HEADS OF LECTURES

ON A COURSE OF

EXPERIMENTAL PHILOSOPHY,

PARTICULARLY INCLUDING

CHEMISTRY,

DELIVERED AT THE NEW COLLEGE
IN HACKNEY.

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THE PREFACE.

Situated, as I happily am, in the neighbourhood of the *New College at Hackney*, an inſtitution that does honour to the Diſſenters, an inſtitution open to all perſons without diſtinction*, and connected as I am by friendſhip with the tutors, I was glad to give it every aſſiſtance in my power; and therefore undertook to read the *Lectures on Hiſtory and General Policy* which I had compoſed when I was tutor at Warrington, and alſo to give another courſe on the ſubject of *Experimental Philoſophy*. With this view I drew up the following *Heads of Lectures*; and, to ſave the ſtudents the trouble of tranſcribing them, they are now printed. To other perſons they may ſerve as a compendious view of the moſt important diſcoveries relating to the ſubject.

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* One gentleman of the Roman Catholic perſuaſion, and ſeveral of the Church of England, are now in the College.

As it was found moſt convenient, with reſpect to the other buſineſs of the college, to confine this courſe to one lecture in a week, I contrived to bring within that compaſs as much of the ſubject of experimental philoſophy as I well could, and eſpecially to include the whole of what is called *chemiſtry*, to which ſo much attention is now given, and which preſents ſo many new fields of philoſophical inveſtigation.

Beſides that the plan of the young gentlemen's ſtudies would not admit of it, I think it moſt adviſable not to trouble beginners with more than a large outline of any branch of ſcience. By this means they are not fatigued by too long an attention to any one ſubject, a greater variety of articles may be brought before them, and in future life they may purſue any of them as much farther as their inclination may diſpoſe, and their ability and opportunity ſhall enable, them to do it.

I do not give any account of the *experiments* introduced into the ſeveral lectures. They will be ſufficiently indicated by the ſubjects of them. They were as many as I could conveniently make within the time; and where the experiments themſelves could not be made, I uſually exhibited both the different ſubſtances employed in them, and thoſe that were the reſult of them.

As theſe lectures were calculated for the uſe of the ſtudents at the New College, I prefix an *Addreſs to them*, the ſame in ſubſtance with that which I delivered to them at the cloſe of the ſeſſion of 1791. In it may be ſeen a ſpecimen of the language we hold to them on the ſubject of *politics*, which with reaſonable men will ſerve as an anſwer to the many calumnies that have been thrown out againſt us, as diſaffected to the government of this country.

Such inſtitutions will, indeed, always be objects of hatred and dread to *bigots* and the advocates for *arbitrary power*, but the pride of a truly *free country*. I therefore conclude with my earneſt prayer (the accompliſhment of which the preſent ſtate of the College does not allow us to doubt) ESTO PERPETUA.

THE DEDICATION.

TO THE STUDENTS AT THE NEW COLLEGE IN HACKNEY.

My young Friends,

HAVING drawn up the following *Heads of Lectures* for your uſe, I take the liberty thus publickly to dedicate them to you; and as I earneſtly wiſh for your improvement and happineſs in all reſpects, excuſe me if I take the farther liberty of making a few obſervations, and giving you ſome advice, of a more general nature, adapted to your age and circumſtances.

As you will ſoon leave this place of education, and enter upon your ſeveral profeſſions and employments, I hope your conduct will demonſtrate to the world the ſolid advantages of this inſtitution, and that the great expence attending it, and the beſt attention of the managers, have not been beſtowed in vain.

Many liberal friends of ſcience, of virtue, and of religion, have contributed to procure you the advantages which you enjoy. They have ſpared no pains to provide able and careful tutors, and you have had every other advantage for the proſecution of your ſtudies that they could procure you, unclogged by any ſubſcription to articles of faith, or obligation of any other kind, beſides ſuch as they have deemed neceſſary for your own good, and to give the inſtitution its greateſt effect. This is an advantage you could not have found elſewhere, at leaſt in this country. And in every ſeminary of education much more depends upon opportunity for ſtudy, free from any obſtruction, and undue bias, than upon the ability of tutors; though there is an additional advantage when they are able men, and eminent in the branches of ſcience which they undertake to teach. But this is by no means ſo eſſential as many other circumſtances.

Whatever be the qualifications of your tutors, your improvement muſt chiefly depend upon yourſelves. They cannot *think* or *labour* for you. They can only put you in the beſt way of thinking and labouring for yourſelves. If, therefore, you get knowledge, you muſt acquire it by your own induſtry. You muſt form all concluſions, and all maxims, for yourſelves, from premiſes and *data* collected, and conſidered by yourſelves. And it is the great object of this inſtitution to remove every bias the mind can lie under, and give the greateſt ſcope to true freedom of thinking and inquiry. And provided you be intelligent and virtuous men, and good citizens, it will be no cauſe of regret to the friends of this inſtitution, if, with reſpect to *religion*, or *politics*, you adopt ſyſtems of principles, and maxims of conduct, very different from theirs.

Give me leave, now that I am addreſſing you as *young men*, and young *ſtudents*, to ſuggeſt a caution on a ſubject, of the importance of which it is hardly poſſible that you ſhould be ſufficiently aware, becauſe it is only impreſſed by that *experience* which you have not yet had. I mean that degree of vanity which generally accompanies the acquirements that diligent perſons of your age make in places of liberal education, and the contempt they are too apt to entertain for thoſe who have not made the ſame proficiency with themſelves. And I aſſure you, that in the obſervations I ſhall make on this ſubject, I have no view whatever to any thing that I have obſerved, or heard, of any of you in particular. But I have been in your ſituation myſelf, and I know the importance of theſe obſervations to ſtudents in general.

You are now at an age in which young perſons uſually make the moſt ſenſible advances in knowledge, and in which the underſtanding appears to ripen in the moſt rapid manner. You are able to ſay every year, every month, and almoſt every day, what particular advances you have made, and how much you know more than you did before. And being taught, and accuſtomed, to expreſs your thoughts in writing, you find yourſelves qualified to do this in a manner of which you had no idea, or expectation, but a little time ago. You alſo perfectly remember what you have ſo recently learned, and in many reſpects may be more particular and exact than even your tutors themſelves.

The almoſt unavoidable effect of this is a high idea of your own powers and attainments, and too often a proportionable contempt of thoſe who, not having had equal advantages, cannot do what you are eaſily capable of. A certain degree of vanity is, therefore, excuſable in young perſons; and, indeed, it is by means of it that they are excited to exert themſelves in a manner that they would not otherwiſe have done. But be careful that this temper be not indulged to exceſs, for it will then be found to have ſerious ill conſequences; the leaſt of which is the precluding future improvement, from being already ſatisfied with yourſelves, and conſcious of a ſufficient ſuperiority over others.

The foundation of this ſelf-conceit, on account of literary attainments, will be found to be extremely weak. In fact, we learn more before the period to which you are now arrived, and I hope you will continue to learn more after it, without its being ſo much noticed; and the *ability* that is diſcovered in the acquirements which are the ſubjects of this vanity is not greater than appears on other occaſions. Only they are not ſo conſpicuous.

What we all learn in the firſt three years of our lives, is much more extraordinary in its nature than all that we acquire afterwards. I mean the perfect uſe of our limbs, and the elements of ſpeech. What we learn in a month in that early period of life, could not, if we were brought up in the ignorance of it, be learned in a year at any ſubſequent period. But theſe acquirements being univerſal, and what the circumſtances in which we are all neceſſarily in compel us to learn, it does not appear extraordinary in any particular individual. Alſo, the proficiency that boys make at a grammar ſchool, in which, in general, the dead languages only are taught (a knowledge of which is commonly the reſult of ſevere application) is too common to be the cauſe of much ſelf-conceit. But the advances that are made at places of liberal education are both leſs common, and of a more conſpicuous nature.

You will alſo find, if you continue your application to ſtudy, that it is only the elements of ſcience that you can acquire here, and that if you live many years, they will bear but a ſmall proportion to your future acquirements. But thoſe future acquirements, in conſequence of their bearing a leſs proportion to your whole ſtock of knowledge, will not be ſo conſpicuous. Thus, though all the buildings that in one year are added to ſuch a city as London would make a pretty large country town, they bear ſo ſmall a proportion to what was built before, that they are not much noticed; whereas, had half the quantity of building been erected in a place where no houſe had exiſted before, it would have been a memorable event in the hiſtory of the country.

Alſo, as in old cities many buildings will fall to decay, while new ones are added; you muſt expect to forget much of what you now know. No man can give equal attention to every object; and as we advance in life, we, in general, only learn new things at the expence of the old ones. But then they are the more valuable articles of knowledge, the more general and leading principles, which remain with us; while the more uſeleſs ones, things to which we give leſs attention becauſe we find them to be of leſs uſe, diſappear. Yet it is no uncommon thing for ingenious ſtudents to deſpiſe old ſcholars who are not ſo ready in the *minutiæ* of literature, though they may have forgotten more than thoſe youths ever knew, and may retain what they cannot acquire without forgetting as much.

Another obſervation proper to leſſen the conceit of literary men, is, that genius is not confined to *them*, but is equally great, though not equally conſpicuous, in every other line of life, and eſpecially in manufactures and the arts. Here, however, diſcoveries equal, with reſpect to *ſagacity*, to thoſe of Newton, contribute little to poſthumous fame, becauſe the diſcoverers are not writers.

But the greateſt branch of intellectual

excellence, with reſpect to which every other is nothing, and which, from its nature, can never be foundation of any ſelf-conceit, is *virtue*, or right diſpoſitions of mind, leading to right conduct in life. Proper ſentiments, and juſt affections of mind, ariſe from juſt, and often comprehenſive, views of things, paſt, preſent, and to come. And if the real greatneſs of any thought, or action, be eſtimated by the number of elements that conſtitute it, and its remoteneſs from the dictates of ſenſe and natural appetite, a virtuous and pious man will appear to be a much more dignified character, more proper to be viewed with admiration and eſteem, than the greateſt ſcholar; diſcovering, in fact, greater comprehenſion and force of mind. I mean, however, that virtue which is the reſult of reflection, of diſcipline, and much voluntary exertion, which, though operating with equal promptneſs and facility, is as much ſuperior to mere *innocence*, and what is commonly called *good nature*, as motions ſecondarily automative are to thoſe that are primarily ſo; a compariſon which you who have ſtudied *Hartley's Theory of the Mind* will ſee the force of.

Theſe conſiderations I take the liberty to ſuggeſt, as being proper to leſſen that vanity which is ſo incident to thoſe who diſtinguiſh themſelves in the fields of literature, and which, operating like the acquiſition of riches, or power, or any poſſeſſion that is *rare* among men, inſtead of enlarging, may tend to contract the mind, by confining its attention to itſelf. Beginning with a generous emulation, it proceeds to envy and jealouſy, and ends in actual hatred and malignity, againſt which you cannot, ſurely, be too ſtrongly put upon your guard; this being the greateſt depravity to which human nature is ſubject, and which yet, like any other vice, may be in full poſſeſſion of the mind, without the perſon himſelf knowing, or ſuſpecting it; unleſs he give more attention to his feelings than moſt perſons do. If no man ever thought himſelf to be avaricious, or cruel, can it be expected that any perſon ſhould ever diſcover that he is too ſelf-conceited?

Better, however, infinitely better, were it to rank with the mereſt dunces, than have the conceit and malignity (produced originally from conceit) of ſome who have diſtinguiſhed themſelves the moſt as linguiſts, critics, and poets. Even the ſtudy of nature, though, from its vaſt extent, it is leſs apt to produce this baneful effect, is not always a ſufficient guard againſt it. This is an affecting and an alarming conſideration. But in the intellectual, as in the civil and commercial world, we gain nothing but at the riſk of ſome loſs; and in this caſe the poſſible gain is worth the riſk of even this great loſs.

For when literary and ſcientific excellence coincide with that which is of a moral nature, it adds unſpeakably to the value of a character. Ingenuity coupled with modeſty, and great genius with benevolence and true piety, conſtitute the perfection of human character, and is what we ſhould ever have in view. And a courſe of education in which both theſe objects are equally attended to, is the only one that deſerves to be called *liberal*: but ſuch as, I hope, you have found this to be.

Give me leave further to obſerve to you, that the time that you ſpend in a place of liberal education is of more importance to you than you can be at preſent aware of. Whatever be the ſphere of life for which you are deſtined, the probability is, that you will hereafter have but little leiſure for reading and ſtudying, compared to what you have now. Beſides, general maxims of all kinds, ſuch as are the foundation of all our future conduct, in morals, religion, or politics, are generally formed at your time of life. From this period expect no great change in your opinions, or conduct; becauſe now it is that you give particular attention to the forming your opinions on all ſubjects of importance; ſo that very little that is materially new to you can be expected to occur to you in future life, and almoſt every thing that you would chooſe to read will only tend to confirm you in the general principles that you will now adopt. There are, no doubt, exceptions to this, as well as every other general obſervation; but it is wiſdom to ſuppoſe, and to act upon the ſuppoſition, that we are conſtituted as the generality of mankind are, and that we ſhall feel, and act, as they do. Since, then, ſo much depends on the leading principles and maxims which you will now adopt, be it your care to form juſt and good ones, and let no authority of tutors, or others, have any undue influence over you. In all caſes think and judge for yourſelves, and eſpecially on all ſubjects of importance, and with as much attention as you can give to them.

It may not be amiſs, in the preſent ſtate of things, to ſay ſomething reſpecting another ſubject, which now commands univerſal attention. You cannot but be appriſed, that many perſons entertain a prejudice againſt this College, on account of the republican, and, as they chooſe to call them, the licentious, principles of government, which are ſuppoſed to be taught here. Show, then, by your general converſation, and conduct, that you are the friends of peace and good order; and that, whatever may be your opinions with reſpect to the beſt form of government for people who have no previous prejudices or habits, you will do every thing in your power for the preſervation of that form of it which the generality of your countrymen approve, and under which you live, which is all that can be reaſonably expected of any ſubject. As it is not neceſſary that every good ſon ſhould think his parent the wiſeſt and beſt man in the world, but it is thought ſufficient if the ſon pay due reſpect and obedience to his parent; ſo neither is it to be expected that every man ſhould be of opinion that the form of govenment under which he happens to be born is the beſt of all poſſible forms of government. It is enough that he ſubmit to it, and that he make no attempt to bring about any change, except by fair reaſoning, and endeavouring to convince his countrymen, that it is in their power to better their condition in that reſpect, as well as in any other. Think, therefore, ſpeak, and write, with the greateſt freedom on the ſubject of government, particular or general, as well as on any other that may come before you. It can only be avowed tyranny that would prevent this. But at the ſame time ſubmit yourſelves, and promote ſubmiſſion in others, to that form of government which you find to be moſt approved, in this country, which at preſent unqueſtionably is that by *King*, *Lords*, *and Commons*.

As to *religion*, we may, ſurely, be allowed to think and act entirely for ourſelves; in all caſes obeying God and conſcience rather than man. But let us be thankful for the degree of liberty that we are allowed, though it be not all that we are juſtly entitled to; and let us not uſe any other means than reaſon and argument in order to better our condition. By this peaceable and ſteady conduct we ſhall at length convince thoſe who will hear reaſon, that we are entitled to greater conſideration; and doubt not but whatever is *true* and *right*, will finally prevail, and be univerſally eſtabliſhed.

That any of your tutors, or any of the

friends of this inſtitution, wiſh to promote reformation, in church or ſtate, by any other means than thoſe of reaſon, and argument, is a *calumny*, utterly void of foundation, or probability. But your conduct, diſperſed as you will ſoon be in different parts of the country, will be the beſt means of refuting it. Let us leave the method of proceeding by *riot* and *tumult* to thoſe perſons to whoſe ſchemes ſuch proceedings are congenial. Truth ſtands in no need of ſuch ſupport, and will always triumph when aſſailed by ſuch weapons. In return, then, for the advantages which you have enjoyed in this inſtitution, do it this ſervice; and in recommending it, I truſt you are doing ſubſtantial ſervice to the cauſe of liberty and truth; and conferring a moſt important benefit on your country, and on mankind.

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LECTURES
ON
EXPERIMENTAL PHILOSOPHY.

LECTURE I.

The Introduction.

THE object of experimental philoſophy is the knowledge of nature in general, or more ſtrictly, that of the properties of natural ſubſtances, and of the changes of thoſe properties in different circumſtances. This knowledge can only be attained by *experiment*, or *obſervation*; as that clay is capable of becoming hard by means of fire, and thereby being made into bricks, and that by the ſame means limeſtone can be converted into quick-lime, and by the addition of water and ſand, make mortar. It is by obſervation alſo that we diſcover that ſtones and other heavy bodies fall to the ground, and that a magnet will attract iron. In other words, experimental philoſophy is an inveſtigation of the wiſdom of God in the works and the laws of nature, ſo that it is one of the greateſt objects to the mind of man, and opens a field of inquiry which has no bounds; every advance we make ſuggeſting new doubts and ſubjects of farther inquiry.

The uniformity we diſcover in the properties of natural ſubſtances enables us to lay down general rules, or principles, which, being invariable, we call *the laws of nature*; and by our knowledge of theſe laws we are able to predict, and at our own pleaſure to produce, particular reſults, and this is the ſource of all the powers of man. It is the direction we acquire of the powers of nature; ſo that, as Lord Bacon obſerved, *knowledge is power*.

All arts and manufactures are derived from ſcience. Thus the doctrine of *mechanics* is an application of the law of gravitation. Every thing we are capable of doing by means of the ſteam-engine is derived from our knowledge of the properties of water in ſteam; and all the great effects of gunpowder we owe to our knowledge of the compoſition, and chemical properties, of that ſubſtance.

Every new appearance in nature is preceded by ſome new circumſtance, and to this, or rather to ſomething always attending it, we ſay that the appearance is *owing*. This circumſtance we therefore call the *cauſe*, and the new appearance the *effect* of that cauſe. Thus we ſay that the union of phlogiſton to a particular kind of earth is the cauſe of its becoming a metal.

It is one of the principal rules of philoſophizing to admit no more cauſes than are neceſſary to account for the effects. Thus, if the power of gravity, by which heavy bodies fall to the earth, be ſufficient to retain the planets in their orbits, we are authorized to reject the *Carteſian Vortices*. In other words, we muſt make no more general propoſitions than are neceſſary to comprehend all the particulars contained in them. Thus, after having obſerved that iron conſiſts of a particular kind of earth united to phlogiſton, and that it is ſoluble in acids; and that the ſame is true of all other metallic ſubſtances, we ſay, univerſally, that all metals conſiſt of a peculiar earth and phlogiſton, and that they are all ſoluble in ſome acid.

Of the circumſtances which occaſion a change in the properties of bodies, ſome are the addition of what are properly called *ſubſtances*, or things that are the objects of our ſenſes, being *viſible*, *tangible*, or having *weight*, &c. Thus the addition of an acid changes an alkali into a neutral ſalt. But other changes are occaſioned either by a change of texture in the ſubſtance itſelf, or the addition of ſomething that is not the object of any of our ſenſes. Thus, a piece of ſteel becomes a magnet by the touch of another magnet, and a drop of glaſs acquires the property of flying aſunder by a ſmall fracture, in conſequence of falling when red hot into cold water. Such alſo, in the opinion of ſome, is the difference between hot and cold ſubſtances.

Till the nature of the cauſe be aſcertained,

tained, it is convenient to make uſe of the term *principle*, as including both of the above-mentioned cauſes of the change of properties in bodies. Thus, whatever be the real cauſe of gravity, or of inflammability, we may ſpeak of the *principle of gravity*, or of *inflammability*; whether, with Newton, we ſuppoſe gravity to be occaſioned by a fluid pervading the whole univerſe, which he termed *æther*, and whether inflammability be cauſed by the preſence of a real ſubſtance called phlogiſton, or not. In this manner we uſe the letters x and y to denote unknown quantities in algebra.

When changes are made in ſubſtances by the addition of other ſubſtances, they make what is called a *chemical union*; and in this caſe the properties of the compound cannot with any certainty be deduced from thoſe of the component parts, but muſt be aſcertained by freſh experiments. Thus, from the ſpecific gravities, or the degrees of fuſibility, of two metals, thoſe of the compound cannot be predicted. Neither water nor acid of vitriol will ſeparately diſſolve iron, ſo as to produce inflammable air, but both together will do it. However, the properties of ſimilar compounds are ſimilar to one another. Thus, all metals diſſolved in acids are precipitated by mild alkalis. This chemical union of two ſubſtances we aſcribe to a certain *elective attraction*, or *affinity* that ſubſiſts between them, in conſequence of which they unite with one another whenever a proper opportunity offers, in preference to thoſe ſubſtances to which they were before united. Thus the vitriolic acid, having a ſtronger affinity with the vegetable alkali which is the baſis of nitre, will unite with that alkali, and with it form another compound, called *vitriolated tartar*, while the acid of nitre, being detached from its baſe, is collected ſeparately.

When two ſubſtances compoſe one liquid, and a third, which has a ſtronger affinity with either of the two parts than they have with each other, is added to them, it will unite with that part, and take its place in the ſolution, while the other will in many caſes be precipitated, and may be collected. Thus the earth of alum is precipitated from a ſolution of alum by ſalt of tartar. This is the caſe of *ſimple affinity*.

When both the ſubſtances are compounds, the component parts of which have a weaker affinity with each other than they have with thoſe of the other compound, two new combinations are formed, and this is called a caſe of *double affinity*. Thus when phlogiſticated alkali is poured into a ſolution of green vitriol, the acid of the vitriol unites with the alkali, while the phlogiſton joining the calx of iron makes Pruſſian blue.

All nature lying open to our inveſtigation, we muſt conſider the different parts in ſome order. But it is not very material which we adopt, becauſe, begin where we will, the properties of the ſubſtances we firſt treat of will be connected with thoſe which muſt be particularly conſidered afterwards, the changes in one ſubſtance being occaſioned by its union with another. It will be impoſſible, for example, to explain the properties of metals without conſidering the *acids*, becauſe by their union with acids very important changes are made in their properties.

There have been three principal methods of arranging natural ſubſtances. One is according to the *three kingdoms*, as they are called, into which they have been diſtributed, viz. the *mineral*, the *vegetable*, and the *animal*. Another is according to the *elements* which enter into their compoſition, and a third according to the *form* in which they are uſually found, viz. *aerial*, *fluid*, or *ſolid*. Upon the whole this laſt appears to me to be the moſt convenient, eſpecially as it is eaſy to intermix general obſervations concerning the other diviſions when they are particularly wanted. As there will be frequent occaſion to ſpeak of the component and elementary parts of all ſubſtances, I ſhall here obſerve, that, according to the lateſt obſervations, the following appear to be the elements which compoſe all natural ſubſtances, viz. *dephlogiſticated air*, or the *acidifying principle*; *phlogiſton*, or the *alkaline principle*; the different *earths*, and the principles of *heat*, *light*, and *electricity*. Beſides theſe, there are the following principles which have not been proved to be ſubſtances, viz, *attraction repulſion*, and *magnetiſm*. By the help of theſe principles we are able, according to the preſent ſtate of natural knowledge, to explain all the appearances that have yet occurred to us.

LECTURE II.

Of the Properties of all Matter.

Before I conſider the properties of particular ſubſtances, it will be proper to mention thoſe which are common to them all. But I ſhall firſt obſerve, that the term *ſubſtance* has no proper idea annexed to it, but is merely a convenience in ſpeech; ſince we cannot ſpeak of the properties of ſubſtances, ſuch as *hard*, *round*, *coloured*, &

&c. &c. (which circumſtances alone affect our ſenſes, and thereby give proper ideas) without ſaying that they inhere in, or belong to, ſome *thing*, *ſubſtance*, or *ſubſtratum*. The terms *being* and *perſon* are alſo in the ſame predicament.

One property of all ſubſtances is *extenſion*, ſince they all occupy ſome portion of ſpace.

The incapacity of any ſubſtance to change its place has been termed, though improperly, the *vis inertiæ* of matter. It is ſufficient to ſay, that neither this, nor any other effect can be produced without a cauſe.

Infinite diviſibility is a neceſſary property of all extended ſubſtance; and from this circumſtance it will follow, that the ſmalleſt quantity of ſolid matter may be made to fill the largeſt ſpace, and yet none of the pores ſhall exceed the ſmalleſt given magnitude; and conſequently, that, for any thing we know to the contrary, all the bodies in the univerſe may be comprized in the ſmalleſt ſpace.

Another property uſually aſcribed to all matter is *impenetrability*, or the neceſſary excluſion of any ſubſtance from the place occupied by another. But the only proof of impenetrability is the *reſiſtance* that we find to our endeavours to put one ſubſtance into the place of another; and it is demonſtrated by experiments, that this reſiſtance is not occaſioned by the actual contact of the ſubſtances, but by a power of repulſion acting at a real diſtance from their ſurfaces. It requires a conſiderable force to bring two ſolid ſubſtances into as near contact as the particles of the ſame ſubſtance; and that *theſe* are not in actual contact is evident, from their being capable of being brought nearer by cold; and this is moſt remarkable with reſpect to the heavieſt, that is, the denſeſt, of all ſubſtances, viz. the metals.

A more poſitive argument for the penetrability of matter is, that the particles of light, after entering the denſeſt tranſparent ſubſtance, do not appear to meet with any obſtruction to their progreſs till they come to the oppoſite ſide.

The powers of *attraction* and *repulſion* ſeem to be common to all matter, and the component parts of all ſubſtances are kept in their places by the due balance of thoſe oppoſite powers. If, by any means, the particles of any ſubſtance be removed beyond their ſphere of mutual attraction, they repel one another, as thoſe of water when it becomes ſteam.

Of the different kinds of attraction, that of *gravitation* ſeems to extend to the greateſt poſſible diſtance; but that which keeps together the parts of the ſame ſubſtance, thence called the *attraction of coheſion*, and the different kinds of chemical attractions, called *affinities*, only act at a ſmall diſtance. Of the cauſes of theſe attractions we are entirely ignorant.

Of Aeriform Subſtances.

Aeriform ſubſtances, of which the air that we breathe is one, though inviſible, are real ſubſtances, as appears by their excluding other ſubſtances.

That the air has *weight* appears by actually weighing a veſſel before and after it is exhauſted of air by means of an air-pump (an inſtrument contrived for that purpoſe) by its burſting a bladder, and various other experiments.

Air, being a fluid, preſſes in all directions, as in the experiment of the fountain in *vacuo*, and others.

The weight of the air is the cauſe of the ſuſpenſion of mercury in a barometer, and of the action of pumps. The weight of atmoſpherical air is to that of water in the proportion of about 1 to 800, ſo as to preſs with the weight of about fourteen pounds on every ſquare inch of ſurface.

Air, being an elaſtic fluid, is capable of occupying more or leſs ſpace according to the preſſure which it ſuſtains, as appears by a bladder partially filled with air being expanded when the air is drawn from a receiver in which it is put, by means of the air-pump, and compreſſed in the condenſing engine, an inſtrument the reverſe of the air-pump.

Air is neceſſary to the conveyance of ſound, to the exiſtence of flame, and to animal life.

LECTURE

LECTURE III.

Of Atmoſpherical Air.

THE firſt ſpecies of air that offers itſelf to our conſideration is that of the atmoſphere, which appears to conſiſt of a mixture of two kinds of air, of different and oppoſite qualities, viz, dephlogiſticated and phlogiſticated, in the proportion of about one third of the former to two thirds of the latter. It is by means of the former of theſe two ingredients that it is capable of ſupporting flame and animal life.

O1
N2

This compoſition of atmoſpherical air is proved by ſeveral ſubſtances abſorbing the dephlogiſticated air, and leaving the phlogiſticated. All theſe proceſſes have been termed *phlogiſtic*, becauſe the effect is not produced but by ſubſtances ſuppoſed to contain phlogiſton in a volatile ſtate; and by the affinity between phlogiſton and the dephlogiſticated part of the air, the one is ſeparated from the other. Of theſe proceſſes are the calcination of metals, a mixture of iron-filings and ſulphur, liver of ſulphur, the burning of phoſphorus, and the effluvia of flowers.

In ſome caſes, however, it is not ſo clear that any thing is emitted from the ſubſtance that produces this effect; for water deprived of all air will abſorb the dephlogiſticated part of the atmoſpherical in preference to the phlogiſticated part.

As the purity of atmoſpherical air, or its fitneſs for reſpiration, depends upon the proportion of the dephlogiſticated air that it contains, any of the above-mentioned proceſſes will ſuffice to determine it. The more any given quantity of air is diminiſhed by any of them, the purer it was before the diminution. But this effect is produced the moſt quickly by a mixture of nitrous air, or firing inflammable air in it, being almoſt inſtantaneous.

In order to meaſure the purity of air, it is convenient to take more of the nitrous or inflammable air than is neceſſary to ſaturate the dephlogiſticated air it contains. Equal quantities of each beſt anſwer the purpoſe. Suppoſing a given quantity of atmoſpherical air to be mixed with an equal quantity of nitrous air, and the reſiduum to be 1.1 meaſure, the proportion of dephlogiſticated and phlogiſticated air in it may be found by the following arithmetical operation, it being here taken for granted that one meaſure of pure dephlogiſticated air will ſaturate two meaſures of pure nitrous air.

2. 0 viz. one of each.
1. 1 the reſiduum.

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3) 0. 9 the quantity that has diſappeared.
0. 3 the dephlogiſticated air contained in the meaſure of the air examined.

And this ſubſtracted from 1. leaves .7 for the proportion of phlogiſticated air in it.

LECTURE IV.

oxygen Gass

Of Dephlogiſticated Air.

DEPHLOGISTICATED air, which is one of the component parts of atmoſpherical air, is a principal element in the compoſition of acids, and may be extracted by means of heat from many ſubſtances which contain them, eſpecially the nitrous and vitriolic; as from nitre, red precipitate, the vitriols, and turbith mineral, and alſo from theſe two acids themſelves, expoſed to a red heat in an earthen tube. This kind of air is alſo contained in ſeveral ſubſtances which had attracted it from the atmoſphere, as from precipitate *per ſe*, *minium*, & *manganeſe*.

Dephlogiſticated air is likewiſe produced by the action of light upon green vegetables; and this ſeems to be the chief means employed by nature to preſerve the purity of the atmoſphere.

It is this ingredient in atmoſpheric air that enables it to ſupport combuſtion and animal life. By means of it the moſt intenſe heat may be produced, and in the pureſt of it animals will live nearly five times as long as in an equal quantity of atmoſpherical air.

In reſpiration, part of this air, paſſing the membrane of the lungs, unites with the blood, and imparts to it its florid colour, while the remainder, uniting with phlogiſton exhaled from the venous blood, forms fixed air. It is dephlogiſticated air combined with water that enables fiſhes to live in it.

Dephlogiſticated air is ſomething heavier than atmoſpherical air, and the purity of it is meaſured by mixing with it two equal quantities of nitrous or inflammable air, deducting the reſiduum after the diminution from the three meaſures employed, and dividing the remainder by 3, as in the proceſs for common air.

Nitrogen Gas

Of Phlogiſticated Air.

THE other ingredient in the compoſition of atmoſpherical air is phlogiſticated air. It is procured by extracting the dephlogiſticated part of the common air, as by the calcination of metals, &c. &c. by diſſolving animal ſubſtances in nitrous acid, and alſo by the union of phlogiſton with nitrous air, as by heating iron in it, and by a mixture of iron-filings and ſulphur.

Phlogiſticated air extinguiſhes a candle, is entirely unfit for reſpiration, and is ſomething lighter than common air. It is not capable of decompoſition, except by exploding it together with a ſuperabundance of dephlogiſticated air, and a quantity of inflammable air, or by taking the electric ſpark repeatedly in a mixture of it and dephlogiſticated air. In theſe caſes nitrous acid is formed.

LECTURE

LECTURE V.

Of Inflammable Air.

INFLAMMABLE air is procured from all combuſtible ſubſtances by means of heat and water, and from ſeveral of the metals, eſpecially iron, zink, and tin, by the vitriolic and marine acids.

From oils and ſpirit of wine it is procured by the electric ſpark. By the ſame means alſo alkaline air is converted into it.

That which is procured from metals, eſpecially by ſteam, is the pureſt and the lighteſt, about ten times lighter than common air; in conſequence of which, if a ſufficient quantity be confined in a light covering, it is poſſible to make it carry up heavy weights.

When it is procured from animal or vegetable ſubſtances, it is of a heavier kind, and burns with a lambent flame, of various colours, according to the circumſtances.

Calces of metals heated in inflammable air are revived, and the air abſorbed; and ſince all the metals are revived in the ſame inflammable air, the principle of metallization, or *phlogiſton*, appears to be the ſame in them all.

Pure inflammable air ſeems to conſiſt of phlogiſton and water, and the lambent kinds to be the ſame thing, with the addition of ſome oily vapour diffuſed through it.

LECTURE VI.

Of Nitrous Air.

NITROUS air is procured by diſſolving moſt of the metals, eſpecially iron, mercury, and copper, in the nitrous acid; but that from mercury ſeems to be the pureſt. Nitrous air produced from copper contains a mixture of phlogiſticated air. Some nitrous air is alſo obtained from the ſolution of all vegetable ſubſtances in nitrous acid; whereas animal ſubſtances in the ſame proceſs yield chiefly phlogiſticated air: but in both theſe caſes there is a mixture of fixed air.

This ſpecies of air is likewiſe produced by impregnating water with nitrous vapour. This proceſs continues to have this effect after the water becomes blue, but ceaſes when it turns green; there not then, probably, being a ſufficient proportion of water. Nitrous air is likewiſe produced by volatile alkali paſſing over red hot manganeſe, or green vitriol, when they are yielding dephlogiſticated air. This ſhews that dephlogiſticated air is one ingredient in the compoſition of nitrous air, and the ſame thing appears by pyrophorus burning in it. On the contrary, when nitrous air is made to paſs over red-hot iron, volatile alkali is produced.

Nitrous air is completely decompoſed by a mixture of about half its bulk of dephlogiſticated air, and the produce is nitrous acid. And as nitrous acid is likewiſe formed by the union of inflammable and dephlogiſticated air, one principal ingredient in nitrous air muſt be common to it and inflammable air, or phlogiſton. This air is likewiſe decompoſed by dephlogiſticated nitrous acid, which by this means becomes phlogiſticated. It is alſo decompoſed by a ſolution of green vitriol, which by this means becomes black, and when expoſed to the air, or heated, emits nitrous air, and recovers its former colour. Theſe decompoſitions of nitrous air ſeem to be effected by depriving it of phlogiſton, and thereby reducing it to the phlogiſticated air originally contained in it.

This kind of air is diminiſhed to about one fourth of its bulk by a mixture of iron filings and brimſtone, or by heating iron in it, or calcining other metals in it, when the remainder is phlogiſticated air. All that iron gets in this proceſs is an addition of weight, which appears to be water, but it loſes its phlogiſton, ſo that nitrous air ſeems to contain more phlogiſton, and leſs water than phlogiſticated air.

Nitrous air and dephlogiſticated air will act upon one another through a bladder, but in this caſe there remains about one-fourth of the bulk of nitrous air, and that is phlogiſticated air; ſo that in this caſe there ſeems to be a converſion of nitrous air into phlogiſticated air without any addition of phlogiſton.

Nitrous air is decompoſed by pyrophorus, and by agitation in olive oil, which becomes coagulated by the proceſs. It is alſo abſorbed by ſpirit of turpentine, by ether, by ſpirit of wine, and alkaline liquors.

It is imbibed by charcoal, and both that air which is afterwards expelled from it by heat, and that which remains unabſorbed, is phlogiſticated air.

Nitrous air reſiſts putrefaction, but is diminiſhed by the animal ſubſtances expoſed to it to about a fourth of its bulk, and becomes phlogiſticated air. It is likewiſe fatal to plants, and particularly to inſects.

When nitrous air is long expoſed to iron, it is diminiſhed and brought into a ſtate in which a candle will burn in it, though no animal can breathe it. But this peculiar modification of nitrous air, called *dephlogiſticated nitrous air*, is produced with the greateſt certainty by diſſolving iron in ſpirit of nitre ſaturated with copper, impregnating water with this air, and then expelling it from the water by heat. If bits of earthen ware be heated in this dephlogiſticated nitrous air, a great proportion of it becomes permanent air, not miſcible with water, and nearly as pure as common air, ſo that the principle of *heat* ſeems to be wanting to conſtitute it permanent air.

LECTURE VII.

Of Fixed Air.

HAVING conſidered the properties of thoſe kinds of air which are not readily abſorbed by water, and therefore may be confined by it, I proceed to thoſe which *are* abſorbed by it, and which require to be confined by mercury. There are two kinds, however, in a middle ſtate between theſe, being abſorbed by water, but not very readily; a conſiderable time, or agitation, being neceſſary for that purpoſe. The firſt of theſe is *fixed air.*

This kind of air is obtained in the pureſt ſtate by diſſolving marble, lime-ſtone, and other kinds of mild calcareous earth in any acid. It is alſo obtained by the burning, or the putrefaction, of both animal and vegetable ſubſtances, but with a mixture of both phlogiſticated and inflammable air. Fixed air is alſo produced by heating together iron filings and red precipitate; the former of which would alone yield inflammable air, and the latter dephlogiſticated. Fixed air is therefore a combination of theſe two kinds of air.

Another fact which proves the ſame thing is, that if charcoal of copper be heated in dephlogiſticated air, almoſt the whole of it will be converted into fixed air. On the ſame principle fixed air is produced when iron, and other inflammable ſubſtances, are burned in dephlogiſticated air, and alſo when minium, and other ſubſtances containing dephlogiſticated air, are heated in inflammable air.

That water is an eſſential part of fixed air is proved by an experiment upon *terra ponderoſa aerata*, which yields fixed air when it is diſſolved in an acid, but not by mere heat. If ſteam, however, be admitted to it in that ſtate, it will yield as much fixed air as when it is diſſolved in an acid.

Water abſorbs ſomething more than its own bulk of fixed air, and then becomes a proper acid. Iron diſſolved in this water makes it a proper chalybeate; as without iron it is of the ſame nature with Pyrmont or Seltzer water, which by this means may be made artificially.

Ice will not imbibe this air, and therefore freezing expels it from water.

Fixed air extinguiſhes flame, and is fatal to animals breathing in it. Alſo water impregnated with this air is fatal to fiſhes, and highly injurious to plants. But water thus impregnated will prevent, in a great meaſure, the putrefaction of animal ſubſtances.

Fixed air thrown into the inteſtines, by way of glyſter, has been found to give relief in ſome caſes of putrid diſeaſe.

Of Hepatic Air.

Another ſpecies of air abſorbed by water, but not inſtantly, is termed *hepatic air*, being produced by the ſolution of liver of ſulphur, or of ſulphurated iron, in vitriolic or marine acid.

Water imbibes about twice its bulk of this kind of air, and it is then the ſame thing with the ſulphureous waters of Harrowgate.

Of Phoſphoric Air.

PHOSPHORIC air is produced by the ſolution of phoſphorus in cauſtic fixed alkali. If this air be confined by mercury, it will take fire on being admitted to atmoſpheric, and much more to dephlogiſticated air. After agitation in water it loſes this property, and the reſiduum is merely inflammable air, with no great diminution of its bulk. This kind of air, therefore, probably conſiſts of phoſphorus diſſolved in inflammable air; though it cannot be made by melting it in inflammable air.

LECTURE VIII.

Of Dephlogiſticated Marine Acid Air.

THIS ſpecies of air is produced by heating ſpirit of ſalt with manganeſe; or more readily, by pouring acid of vitriol on a mixture of ſalt and manganeſe, in the proportion of about 16 of the former to 6 of the latter. In this caſe the acid of vitriol decompoſes the ſalt, and the marine acid, diſengaged in the form of air, takes dephlogiſticated air from the manganeſe; ſo that this ſpecies of air ſeems to conſiſt of marine acid vapour, and dephlogiſticated air.

This ſpecies of air has a peculiarly pungent ſmell, and is abſorbed by water as readily as fixed air.

The water takes about twice its bulk of it; and thereby acquires a yellowiſh tinge. Both this air, and the water impregnated with it, diſcharges vegetable colours from linen or cotton, and is thereby uſeful in bleaching.

This air when cold coagulates into a yellowiſh ſubſtance. It diſſolves mercury, and with it forms *corroſive ſublimate.*

Of Phlogiſticated Marine Acid Air.

Besides the preceding kinds of air which are ſlowly abſorbed by water, there are others which are abſorbed by it very rapidly, ſo that they cannot be confined but by mercury.

Of this kind is *phlogiſticated marine acid air*, procured by the acid of vitriol and common ſalt; the former ſeizing upon the alkaline baſis of the latter, and thereby expelling the marine acid in the form of air.

It is called *phlogiſticated* to diſtinguiſh it from *dephlogiſticated marine acid air*, which ſeems to be the ſame thing, with the addition of dephlogiſticated air.

Phlogiſticated marine acid air is heavier than common air. It extinguiſhes a candle with a blue flame. It diſſolves many ſubſtances containing phlogiſton, as iron, dry fleſh, &c. and thereby forms a little inflammable air. Water abſorbs 360 times its bulk of this air, and is then the ſtrongeſt ſpirit of ſalt. It abſorbs one-ſixth more than its bulk of alkaline air, and with it forms the common ſal ammoniac. Its affinity to water enables it to diſſolve ice, and to deprive borax, nitre, and other ſaline ſubſtances, of the water that enters into their compoſition.

LECTURE IX.

Of Vitriolic Acid Air.

VITRIOLIC acid air is procured by heating in hot acid of vitriol almoſt any ſubſtance containing phlogiſton, eſpecially the metals which are ſoluble in that acid, as copper, mercury, &c. This kind of air is heavier than common air, and extinguiſhes a candle, but without any particular colour of its flame. It will not diſlodge the nitrous or marine acids from any ſubſtance containing them.

By its affinity to water it deprives borax of it.

One meaſure of this air ſaturates two of alkaline air, and with it forms the vitriolic ammoniac.

Water imbibes between 30 and 40 times its bulk of this air, and retains it when frozen. Water thus impregnated diſſolves ſome metals, and thereby yields inflammable air.

If this water be confined in a glaſs tube, together with common air, and be expoſed to a long continued heat, it forms real ſulphur, the dephlogiſticated part of the common air being imbibed, and forming real vitriolic acid, which uniting with the phlogiſton in the air, forms the ſulphur. Alſo this air mixed with atmoſpheric air will, without heat, imbibe ſome part of it, and thereby become the common acid of vitriol; ſo that water impregnated with vitriolic acid air, commonly called *ſulphureous*, or *phlogiſticated acid of vitriol*, wants dephlogiſticated air to make it the common acid of of vitriol.

This kind of air is imbibed by oils, which thereby change their colour; whale oil becoming red, olive oil of an orange colour, and ſpirit of turpentine of the colour of amber.

If this air be confined in a glaſs tube by mercury, and the electric ſpark be taken in it, a black tinge will be given to the glaſs contiguous to the ſpark, and this black ſubſtance appears to be mercury ſuper-phlogiſticated; ſince by expoſure to air it becomes running mercury: ſo that the vapour of mercury muſt be diffuſed through every part of this air, to the diſtance of at leaſt ſeveral feet from the ſurface of the mercury.

Of Fluor Acid Air.

Fluor acid air is procured by diſſolving the earthy ſubſtance called *fluor* in vitriolic acid.

This kind of air extinguiſhes a candle, and, like vitriolic acid air, one meaſure of it ſaturates two of alkaline air. It is peculiar to this kind of air to diſſolve glaſs when it is hot.

It ſeems to conſiſt of a peculiar acid vapour united to the ſtony ſubſtance of the fluor; for water being admitted to it abſorbs the acid vapour, and the ſtony ſubſtance is depoſited. By this means it exhibits an amuſing appearance, whether water be admitted to a glaſs jar previouſly filled with that air, or the bubbles of air be admitted, as they are formed, to a quantity of water reſting on mercury.

LECTURE X.

Of Alkaline Air.

Alkaline air is produced by means of heat from cauſtic volatile alkali, and alſo from a mixture of ſal-ammoniac and ſlaked lime, in the proportion of about one-fourth of the former to three-fourths of the latter. In this caſe the marine acid in the ſal-ammoniac unites with the calcareous earth, and the volatile alkali (probably with the aſſiſtance of the water) takes the form of air.

This ſpecies of air is heavier than inflammable air, but lighter than any of the acid airs. Like them, however, it diſſolves ice, and deprives alum, and ſome other ſaline ſubſtances, of the water which they contain. United with fixed air, it makes the concrete volatile alkali; with marine acid air, the common ſal-ammoniac; and with water, the cauſtic volatile alkali.

The electric ſpark, or a red heat, converts alkaline air into three times its bulk of inflammable air; and the calces of metals are revived in alkaline, as well as in inflammable air; but there remains about one-fourth of its bulk of phlogiſticated air. Theſe facts ſhew that alkaline air conſiſts chiefly of phlogiſton.

Miſcellaneous Obſervations relating to Air.

THE *nitrous* acid may be exhibited in the form of air, as well as the vitriolic, the marine, and the fluor acids. But it cannot be confined even by mercury, which it inſtantly diſſolves. It may, however, in ſome meaſure, be confined in a dry glaſs veſſel, from which it will in a great meaſure expel the common air. This nitrous acid air is that red vapour, which is produced by the rapid ſolution of biſmuth, and ſome other metals in the nitrous acid. But the vegetable acid cannot be exhibited in the form of air. It is only capable of being converted into vapour, like water: and in the common temperature of our atmoſphere, returns to a ſtate of fluidity.

Different kinds of air which have no affinity to each other, when once mixed together will not ſeparate, notwithſtanding any difference of ſpecific gravity. Such is the caſe of a mixture of inflammable and dephlogiſticated air, and even of inflammable and fixed air. Without this property alſo, the phlogiſticated air, which conſtitutes the greateſt part of our atmoſphere, being ſpecifically lighter than dephlogiſticated air, of which the other part of it conſiſts, would ſeparate from it, and aſcend into the higher regions of the atmoſphere. Inflammable air, however, will not mix with acid or alkaline air.

Different kinds of air are expanded differently by the ſame degrees of heat; dephlogiſticated air the leaſt, and alkaline air the moſt.

If any fluid, as water, ſpirit of wine, or even mercury, be heated in a porous earthen veſſel, ſurrounded by any kind of air, the vapour of the fluid will paſs through the veſſel *one* way, while the air paſſes the *other*; and when the operation ceaſes, with reſpect to the *one*, it likewiſe ceaſes with reſpect to the *other*.

LECTURE XI.

Of Liquid Subſtances;

AND FIRST OF

WATER.

HAVING conſidered all the ſubſtances that are uſually found in the form of *air*, I come to thoſe that are generally in a *fluid* form, beginning with *water*, which is the principal, if not the only cauſe of fluidity to all the other ſubſtances that I ſhall place in this claſs.

Pure water is a liquid ſubſtance, tranſparent, without colour, taſte, or ſmell; and with different degrees of heat and cold may be made to aſſume the three forms of a ſolid, of a fluid, and of air. Below 32° of Fahrenheit it is ice, and above 212° it is vapour; ſo that in an atmoſphere below 32° it never could have been known to be any thing elſe than a peculiar kind of ſtone, and above 212° a peculiar ſpecies of air.

In paſſing from the ſtate of a ſolid to that of a liquid, water abſorbs a great quantity of the principle, or matter, of *heat*, which remains in it in a *latent* ſtate; and in paſſing from a ſtate of fluid to that of vapour, it abſorbs much more; and this heat is found when the proceſſes are reverſed. It has been obſerved, that when water becomes vapour, it takes the form of ſmall globules, hollow within, ſo as to be ſpecifically lighter than air.

The degree of heat at which water is converted into vapour depends upon the preſſure of the atmoſphere; ſo that in vacuo, or on the top of a high mountain, it boils with little heat; and when compreſſed, as in Papin's digeſter, or in the bottom of a deep pit, it requires much heat. In the former caſe the reſtoring of the preſſure will inſtantly put a ſtop to the boiling, and in the latter caſe the removing of the preſſure will inſtantly convert the heated water into vapour.

The eaſe with which water is converted

into vapour by heat, has given a great power to mechanicians, either by employing the natural preſſure of the atmoſphere, when ſteam is condenſed under a moveable piſtern, in an iron cylinder, which was the principle of the old fire-engine, or by employing the elaſtic power of ſteam to produce the ſame effect, which is the principle of Mr. Watt's ſteam engine.

Water was long thought to be incompreſſible by any external force, but Mr. Canton has ſhewn that even the preſſure of the atmoſphere will condenſe it very ſenſibly.

We do not know any external force equal to that by which water is expanded when it is converted into ice, or into vapour. For though the particles of water approach nearer by cold, yet when it cryſtallizes, the particles arrange themſelves in a particular manner, with interſtices between them; ſo that, on the whole, it takes up more room than before.

Water has an affinity to, and combines with, almoſt all natural ſubſtances, aerial, fluid, or ſolid; but moſt intimately with acids, alkalies, calcareous earth, and that calx of iron which is called *finery cinder*, from which the ſtrongeſt heat will not expel it.

It has been ſuppoſed by ſome, that by frequent diſtillation, and alſo by agitation, water may be converted into a kind of earth; but this does not appear to be the caſe. It has alſo of late been thought, that water is reſolvable into dephlogiſticated and inflammable air; but the experiments which have been alleged to prove this do not ſatisfy me; ſo that, for any thing that appeared till very lately, water might be conſidered as a ſimple element. By means of heat, however, it ſeems to be reſolvable into ſuch air as that of which the atmoſphere conſiſts, viz. dephlogiſticated and phlogiſticated, only with a greater proportion of the former.

Water, with reſpect to ſpecific gravity and temperature, has generally been made the ſtandard to all other ſubſtances; its freezing and boiling points being the limits by means of which thermometers are graduated. Other ſubſtances have alſo been compared with water, as a ſtandard, with reſpect to the capacity of receiving heat, and retaining it in a latent ſtate, as will be ſhewn when we conſider the ſubject of heat.

LECTURE XII.

Of the Nitrous Acid.

UNDER the head of *liquids* I ſhall conſider *acids* and *alkalis*, though ſome of them may be exhibited in the form of air, and others in a ſolid form. Theſe two chemical principles are formed to unite with one another, and then they conſtitute what is called a *neutral ſalt*.

Both acids and alkalis are diſtinguiſhable by their taſte. Another teſt, and more accurate, is, that acids change the blue juices of vegetables red, and alkalis turn the ſyrup of violets green.

Acids are generally diſtinguiſhed according to the three kingdoms to which they belong, viz. *mineral*, *vegetable*, and *animal*. The mineral acids are three, the *nitrous*, the *vitriolic*, and the *marine*.

The nitrous acid is formed by the union of the pureſt inflammable air, or the pureſt nitrous air, with dephlogiſticated air. But it is uſually procured from nitre by means of the vitriolic acid, which, ſeizing its baſe, expels the nitrous acid in a liquid form. On this account this acid is ſaid to be weaker than the vitriolic.

If the nitrous acid be made to paſs through a red-hot earthen tube, it will be decompoſed, and the greateſt part of it be converted into dephlogiſticated air.

Like all other acids, the nitrous acid has a ſtrong affinity to water; but it is not capable of ſo much concentration as the vitriolic. It is generally of an orange or yellow colour; but heat will expel this colour in the form of a red vapour, which is the ſame acid in the form of air, and loaded with phlogiſton; and therefore when it is colourleſs it is ſaid to be dephlogiſticated. But the colourleſs vapour expoſed to heat, or to light, will become coloured again; and the liquid acid imbibing this coloured vapour, becomes coloured as before. This acid tinges the ſkin of a yellow colour, which does not diſappear till the epidermis be changed.

The nitrous acid unites with phlogiſton, alkalis, metallic ſubſtances, and calcareous earth.

By means of its affinity with phlogiſton it occaſions that rapid accenſion called *detonation*, when any ſalt containing this acid, eſpecially nitre, is applied to hot charcoal, or when charcoal is put to hot nitre. In fact, the charcoal burns ſo rapidly by means of the dephlogiſticated air ſupplied by the nitre.

A mixture of ſulphur aſſiſts the accenſion of theſe ſubſtances, and makes gunpowder, in the exploſion of which much nitrous or phlogiſticated air is ſuddenly produced, and expanded by the heat. The application of this force, both to uſeful and deſtructive purpoſes, is well known. If, inſtead of nitre, a ſalt made with dephlogiſticated marine acid be made uſe of, the exploſion is more eaſily produced, and is much more violent. Friction will do this as well as heat.

Nitre alſo enters into the compoſition of *pulvis fulminans*, viz. three parts nitre, two of dry alkali, and one of ſulphur. This compoſition melts, and yields a blue flame, before it explodes.

By means of the affinity of the nitrous acid to *oil*, another ſubſtance containing phlogiſton, it is capable of producing not only a great heat, but even a ſudden flame, eſpecially when mixed with a little vitriolic acid.

Nitrous acid diſſolves all metallic ſubſtances except gold and platina, and in the ſolution nitrous air is produced.

The particular kinds of ſaline ſubſtances formed by the union of the nitrous acid with the ſeveral metals and earths may be ſeen in tables conſtructed for the purpoſe. They are all deliqueſcent.

LECTURE XIII.

Of the Vitriolic Acid.

THE vitriolic acid, ſo called becauſe it was originally procured from *vitriol*, is now generally procured from ſulphur; the dephlogiſticated part of the air uniting with it in the act of burning.

That dephlogiſticated air is eſſential to this acid is evident from the decompoſition of it; for if the vapour of it be made to paſs through a red-hot earthen tube, a great quantity of dephlogiſticated air is procured.

This acid has a ſtrong affinity to water, with which it unites with much heat; and it is capable of greater concentration, or of being made ſpecifically heavier, than any other acid. When pure, it is entirely free from colour and ſmell, owing, probably, to its being free from phlogiſton, which is inſeparable from the nitrous or marine acids.

The vitriolic acid will diſlodge the nitrous, or marine, or any other acid, from their earthy or metallic baſes; from which property it is called the ſtrongeſt of all the acids.

By means of the ſuperior affinity of the vitriolic acid to earths, and eſpecially to *terra ponderoſa*, the ſmalleſt quantity of it in water may be diſcovered by a ſolution of this earth in the marine acid. In this acid the terra ponderoſa is held in perfect ſolution; but with the vitriolic acid it forms a ſubſtance that is inſoluble in water, and therefore it inſtantly appears in the form of a white cloud.

Perhaps chiefly from the ſtrong affinity which this acid has with water, *pyrophorus*, conſiſting of a mixture of alum and ſeveral ſubſtances containing phlogiſton, takes fire ſpontaneouſly on expoſure to the air. It is commonly made of three parts of alum and one of brown ſugar, or of two parts alum, one of ſalt of tartar, and one of charcoal. They muſt be heated till they have for ſome time emitted a vapour that burns with a blue flame.

The ſaline ſubſtances produced by the union of this acid with the ſeveral earths and metals, are beſt exhibited in tables conſtructed for the purpoſe. When united to three of the metals, viz. iron, copper, and zinc, they are called *vitriols*, green, blue, and white. And all the ſubſtances which this acid unites with cryſtallize, and do not deliqueſce.

This acid unites with oil, and the mixture is always black.

When any ſubſtance containing phlogiſton is heated in the vitriolic acid, another ſpecies of the acid, called *ſulphureous*, is formed, of a pungent ſmell. In reality, it is water impregnated with vitriolic acid air. It makes, however, a diſtinct ſpecies of acid, and is diſlodged from its baſe by moſt of the others.

Of the Marine Acid.

The marine acid is procured from common ſalt by the vitriolic acid, which unites with its baſe, the foſſil alkali.

This acid is generally of a ſtraw-colour; but this is owing to an impregnation with ſome earthy matter, moſt of which it readily diſſolves, eſpecially the metallic ones. It is leſs capable of concentration than the vitriolic or nitrous acids, perhaps from a more intimate union of phlogiſton with it. No heat can extract from it any dephlogiſticated air.

Though this is denominated a weaker acid than the nitrous, yet it will take ſilver, lead, or mercury, from their union with the nitrous acid. Upon this principle, a ſolution of theſe metals in the nitrous acid will readily diſcover whether any water contains the marine acid, the latter uniting with the metal diſſolved in the former, and forming with it, if it be ſilver, a *luna cornea*; which being a ſubſtance inſoluble in water, diſcovers itſelf by a cloudy appearance.

The union of the marine acid with earths forms ſalts that eaſily deliqueſce, but with the metals ſuch as are capable of cryſtallization; and ſo alſo is that formed by the union of this acid to terra ponderoſa.

Neither this acid nor the nitrous will diſſolve gold or platina; but a mixture of them, called *aqua regia*, will do it.

The marine acid has a ſtrong affinity to dephlogiſticated air, and will take it from mangane ſe and other ſubſtances; and with this union it becomes a different acid, called *dephlogiſticated marine acid*, being water impregnated with dephlogiſticated marine acid air, deſcribed above.

LECTURE XIV.

Of the Vegetable Acids, and others of a leſs perfect nature.

THE principal of the vegetable acids are the *acetous* and the *tartareous*. The acetous acid is the produce of a peculiar fermentation of vegetable ſubſtances, ſucceeding the *vinous*, in which ardent ſpirit it is procured, and ſucceeded by the *putrefactive*, in which volatile alkali is generated.

Thus wine is converted into vinegar. Crude vinegar, however, contains ſome ingredient from the vegetable ſubſtances from which it was procured: but diſtillation ſeparates them, and makes the vinegar colourleſs; though ſome of the acid is loſt in the proceſs.

The acetous acid is concentrated by froſt, which does not affect the proper acid, but only the water with which it is united. It may likewiſe be concentrated by being firſt combined with alkalies, earths, or metals, and then diſlodged by a ſtronger acid, or by mere heat. Thus the acetous acid, combined with vegetable alkali, forms a ſubſtance that is called the *foliated earth of tartar*; and it may be expelled from it by the vitriolic acid. When combined with copper it makes *verdigris*; and from this union heat alone will expel it in a concentrated ſtate. The acetous acid thus concentrated is called *radical vinegar*. Still, however, it is weaker than any of the preceding mineral acids.

Several vegetables, as lemons, ſorrel, and unripe fruit, contain acids, ready formed by nature, mixed with ſome of the eſſential oil of the plants, which gives them their peculiar flavours. All theſe acids have peculiar properties; but it is not neceſſary to note them in this very general view of the ſubject. Like vinegar, theſe acids may be concentrated by froſt, and alſo by a combination with other ſubſtances, and then expelled by a ſtronger acid.

The *acid of tartar* is very ſimilar to that of vinegar. Tartar, from which it is procured, is a ſubſtance depoſited on the inſide of wine-caſks, though it is alſo found ready formed in ſeveral vegetables. It conſiſts of the vegetable alkali and this peculiar acid. When refined from its impurities, it is called *cryſtals*, or *cream of tartar*. The acid is procured by mixing the tartar with chalk, or lime, which imbibes the ſuperfluous acid, and this is expelled by the acid of vitriol. Or it may be procured by boiling the tartar with five or ſix times its weight of water, and then putting the acid of vitriol to it. This unites with the vegetable alkali, and forms vitriolated tartar; and the pure acid of tartar may be procured in cryſtals, by evaporation and filtration, equal in weight to half the cream of tartar. This acid of tartar is more ſoluble in water than the cream of tartar.

This acid, united to the mineral alkali, makes *Rochelle ſalt*.

Every kind of wood, when diſtilled, or burned, yields a peculiar acid; and it is the vapour of this acid that is ſo offenſive to the eyes in the ſmoke of wood.

A peculiar acid is obtained from moſt

vegetable ſubſtances, eſpecially the farinaceous ones, and from ſugar, by diſtillation with the nitrous acid. This ſeizes upon the ſubſtance with which the acid was united, and eſpecially the phlogiſton adhering to it, and then the peculiar *acid of ſugar* cryſtallizes. Thus with three parts of ſugar, and thirty of nitrous acid, one part of the proper acid of ſugar may be obtained. By the ſame proceſs an acid may be procured from camphor.

The *bark of oak*, and ſome other vegetable ſubſtances, eſpecially nut-galls, contain a ſubſtance which has obtained the name of *the aſtringent principle*; the peculiar property of which is, that it precipitates ſolutions of iron in the form of a black powder, and in this manner *ink* is made. But by ſolution in water and evaporation, cryſtals, which are a proper *acid of galls*, may be obtained.

Amber is a hard ſemitranſparent ſubſtance, chiefly found in Pruſſia, either dug out of the earth, or thrown up by the ſea. It is chiefly remarkable for its electrical property; but by diſtillation in cloſe veſſels there ſublimes from it a concreted acid, ſoluble in 24 times its weight of cold water. Amber ſeems to be of vegetable origin, and to conſiſt of an oil united to this peculiar acid.

The acids I ſhall mention next are of a mineral origin; but being of a leſs perfect nature as acids, I ſhall only juſt note them here.

Borax is a ſubſtance chiefly found in a cryſtallized ſtate in ſome lakes in the Eaſt Indies. It conſiſts of the mineral alkali and a peculiar acid, which may be ſeparated, and exhibited in white flakes, by putting acid of vitriol to a ſolution of it in water. This acid has been called *ſedative ſalt*, from its ſuppoſed uſes in medicine. It is an acid that requires fifty times its weight of water to diſſolve it.

Several other mineral ſubſtances, as *arſenic*, *molybdena*, *tungſten*, and *wolfram*, in conſequence of being treated as the preceding vegetables ones, have been lately found to yield peculiar acids. They are alſo produced in a concrete ſtate, and require a conſiderable proportion of water to make them liquid; but as the water in which they are diſſolved turns the juice of litmus red, and as they alſo unite with alkalis, they have all the neceſſary characteriſtics of acids.

LECTURE XV.

Of the Phoſphoric Acid.

THE moſt important acid of *animal* origin, though it has lately been found in ſome mineral ſubſtances, is the *phoſphoric.*

Phoſphorus itſelf is a remarkable ſubſtance, much reſembling ſulphur, but much more inflammable. It has been procured chiefly, till of late, from urine, but now more generally from *bones*, by means of the vitriolic acid, which unites with the calcareous earth of which bones conſiſt, and ſets at liberty the phoſphoric acid, or the baſe of that acid, with which it was naturally combined. The acid thus procured, mixed with charcoal, and expoſed to a ſtrong heat, makes phoſphorus.

This ſubſtance burns with a lambent flame in the common temperature of our atmoſphere, but with a ſtrong and vivid flame if it be expoſed to the open air when moderately warm. In burning it unites with the dephlogiſticated air of the atmoſphere, and in this manner the pureſt phoſphoric acid is produced.

This acid is alſo procured in great purity by means of the nitrous or vitriolic acids, eſpecially the former, which readily combines with the phlogiſton of the phoſphorus, and thus leaves the acid pure. In this proceſs phlogiſticated air is produced.

This acid is perfectly colourleſs, and when expoſed to heat loſes all its water, and becomes a glaſſy ſubſtance, not liable to be diſſipated by fire, and readily uniting with earths.

United to the mineral alkali, it forms a neutral ſalt, lately introduced into medicine. United to the mineral and vegetable alkalis naturally contained in urine, it has obtained the name of *microcoſmic ſalt*, frequently uſed as a flux for mineral ſubſtances with a blow-pipe.

Beſides the phoſphoric, there are other acids of an animal origin; as that of *milk*, that of *ſugar of milk*, that of the *animal calculus*, and that of *fat*.

The acid of milk is the ſour whey contained in butter-milk, which, by a tedious chemical proceſs, may be obtained pure from any foreign ſubſtance.

The ſugar of milk is procured by evaporating the whey to dryneſs, then diſſolving it in water, clarifying it with whites of eggs, and evaporating it to the conſiſtence of honey. In this ſtate white cryſtals of the acid of ſugar of milk will be obtained.

By diſtilling theſe cryſtals with nitrous acid, other cryſtals of the proper *acid of ſugar of milk* will be obtained, ſimilar to thoſe of the acid of ſugar.

If the human calculus be diſtilled, it yields a volatile alkali, and ſomething ſublimes from it which has a ſouriſh taſte, and therefore called the *acid of the calculus*. It is probably ſome modification of the phoſphoric acid.

Animal fat yields an acid by diſtillation, or by firſt combining it with quick-lime, and then ſeparating it by the vitriolic acid. Siliceous earth is corroded by this acid.

LECTURE XVI.

Of Alkalis.

THE claſs of ſubſtances that ſeems particularly formed by nature to unite with acids, and thereby form *neutral ſalts*, are the *alkalis*. They have all a peculiar acrid taſte, not eaſily defined. They change the blue juices of vegetables green, or purple, and in common with acids have an affinity with water, ſo as to be capable of being exhibited in a liquid form; though when this water is expelled by heat, ſome of them will aſſume a ſolid form.

Alkalis are of two kinds; the *fixed*,

which have no ſmell, and the *volatile*, which have a pungent one.

The fixed alkalis are of *vegetable* or *mineral* origin. When in a ſolid form, they both melt with a moderate heat, and uniting with earthy ſubſtances, make *glaſs*. With an intenſe heat they are volatilized.

Vegetable alkali is procured by burning plants, and lixiviating the aſhes; a purer kind by the burning of tartar, hence called *ſalt of tartar*; but the pureſt of all is got by the deflagration of nitre; the charcoal uniting with the acid as it aſſumes the form of dephlogiſticated air, and the alkali being left behind.

Mineral alkali is found in aſhes of ſea-weed. It is likewiſe the baſis of ſea-ſalt; from which it is ſeparated by ſeveral proceſſes, but eſpecially by the calx of lead, which has a ſtronger affinity with the marine acid with which it is found combined.

Alkalis united with fixed air are ſaid to be *mild*, and when deprived of it *cauſtic*, from their readineſs to unite with, and thereby *corrode*, vegetable and animal ſubſtances. To render them cauſtic, they are deprived of their fixed air by quick-lime; and in this ſtate they unite with oils, and make *ſoap*.

Alkalis have a ſtronger affinity with acids than metals have with them; ſo that they will precipitate them from their ſolutions in acid menſtruums.

The vegetable fixed alkali has a ſtrong attraction to water, with which it will become ſaturated in the common ſtate of our atmoſphere, when it is ſaid to *deliqueſce*; and having the appearance of *oil*, the ſalt of tartar is thus ſaid to become *oil of tartar per deliquium*. On the other hand, the mineral, or foſſil alkali, is apt to loſe its water in a dry atmoſphere, and then it is ſaid to *effloreſce*. In this ſtate it is often found on old walls.

Volatile alkali is procured by burning animal ſubſtances; in Egypt (from whence, as contained in *ſal ammoniac*, we till of late imported it) from camel's dung; but now from bones, by diſtillation. To the liquor thus procured they add vitriolic acid, or ſubſtances which contain it. This acid unites with the alkali, and common ſalt being put to it, a double affinity takes place. The vitriolic acid uniting with the mineral alkali of the ſalt, makes *Glauber ſalt*, and the marine acid uniting with the volatile alkali, makes *ſal ammoniac.* Slaked lime added to this, unites with the marine acid of the ammoniac, and ſets looſe the volatile alkali in the form of *alkaline air*, which combining with water, makes the liquid cauſtic volatile alkali. If chalk (containing calcareous earth united with fixed air) be mixed with the ſal ammoniac, heat will make the calcareous earth unite with the marine acid, while the fixed air of the chalk will unite with the volatile alkali, and aſſume a ſolid form, being the *ſal volatile* of the apothecaries.

LECTURE XVII.

Of Liquid Inflammable Subſtances.

Of liquid inflammable ſubſtances the principal is *ſpirit of wine*, ſometimes called *ardent ſpirit*, and, when highly rectified, *alcohol.* It is obtained from vegetable ſubſtances by their going through the vinous fermentation. It is conſiderably lighter than water, colourleſs, and tranſparent, has a peculiar ſmell and taſte, and the property of inebriating.

Ardent ſpirit ſeems to conſiſt of a peculiar combination of phlogiſton and water; for when the vapour of it is made to paſs through a red-hot earthen tube, it is reſolved into water and inflammable air. It is highly inflammable, and burns without ſmoke, or leaving any reſiduum; and in the act of burning its phlogiſton ſo unites with dephlogiſticated air as to make fixed air.

Ardent ſpirit mixes readily with water in all proportions, and alſo with eſſential oils, and balſams or reſins, which are the ſame thing inſpiſſated.

By its affinity with eſſential oils, ardent ſpirit extracts them from aromatic plants; and theſe liquors have obtained the name of *tinctures*.

When the tinctures are diſtilled, the more volatile parts of the eſſential oils, which come over in diſtillation, have acquired the name of *waters*; as *Lavender water*, *Roſemary water*, &c. and what remains in the ſtill is called the *extract* of the plant. If the tinctures be diluted with much water, the reſinous part of the plant will be obtained pure, and ſeparated from the extractive part, which will remain diſſolved in the water, while the reſin ſeparates from it.

Spirit of wine will not diſſolve the gummy parts of vegetables; and by this means the gummy ſubſtances may be ſeparated from their ſolutions in water, the ſpirit uniting with the water only. On the other hand, if reſins be diſſolved in ſpirit of wine, the affuſion of water will ſeparate them. By means of the affinity of ſpirit of wine with water, it will ſeize upon the water in which ſeveral ſalts are diſſolved, and thus produce an inſtant cryſtallization of them.

Salt of tartar has a greater affinity to water than ſpirit of wine, and by extracting water from it, will aſſiſt in concentrating it; but the beſt method of rendering ſpirit of wine free from water is diſtillation, the ardent ſpirit riſing before the water.

Spirit of wine mixed with the vitriolic and other mineral acids, renders them milder, and thereby more proper for certain medicinal uſes. This is called *dulcifying* them.

Spirit of wine is a powerful antiſeptic, and is therefore of uſe to preſerve vegetable and animal ſubſtances from putrefaction.

Of Æther.

If ſpirit of wine be diſtilled with almoſt any of the acids, the produce is a liquor which has obtained the name of *Æther*, from its extreme lightneſs and volatility, being much lighter, and more volatile, than any other fluid that we are acquainted with. It is highly inflammable, but the burning of it is accompanied with ſmoke, and ſome ſoot; and on this account it is a medium between ſpirit of wine and oil, the acid having taken from the ſpirit of wine part of the water that was eſſential to it, at the ſame time that it communicated ſomething of its acid peculiarly modified; ſince æthers have different properties according to the acids by which they are made; as the *vitriolic*, the *nitrous*, the *marine*, and the *acetous*. No æther, however, can be made from the marine acid till it has been in ſome meaſure dephlogiſticated; from which it may be inferred, that dephlogiſticated air is neceſſary to the compoſition of æther. Vitriolic æther is the moſt common, in conſequence of the proceſs by which it is made being the eaſieſt.

Æther does not mix with water in all proportions, like ſpirit of wine, but ten parts of water will take up one of æther. It eaſily mixes with all oils.

It is ſomething remarkable, that though æther will not diſſolve gold, it will take from aqua regia the gold that has been previouſly diſſoved in it.

By the quick evaporation of æther a conſiderable degree of cold may be procured; and on this principle it has ſometimes been applied to relieve the head-ach and other pains.

LECTURE XVIII.

Of Oil.

OIL is a liquid inflammable ſubſtance, of great tenacity, diſpoſed to pour in a ſtream rather than in drops. It is little, if at all, ſoluble in water. It burns with ſmoke and ſoot, and leaves a reſiduum of a coaly ſubſtance. It conſiſts of acid and water combined with phlogiſton.

All oil is the produce of the vegetable or animal kingdom, no proper mineral ſubſtance containing any of it.

By diſtillation oil is in part decompoſed, and by this means the thicker kinds of oil are rendered thinner and more volatile, the acid, to which their conſiſtence is chiefly owing, being loſt in the proceſs. By repeated diſtillation it is ſuppoſed that all oils may be brought almoſt to the ſtate of æther, and even of ardent ſpirit.

Acids act powerfully upon oils, but very differently, according to the nature of each. Alkalies alſo combine with oils, and the leſs thin and volatile they are, the more eaſily are they ſoluble in alkalies. The union of alkali and oil makes *ſoap*. All oil diſſolves ſulphur, and with it makes what is called a *balſam*. Oils alſo diſſolve metallic ſubſtances, but moſt ſenſibly copper and lead. United with the calx of lead, it is uſed in painting.

Oil not readily mixing with water, it will diffuſe itſelf over its ſurface, and, notwithſtanding its tenacity, it will do this very rapidly, and to a great extent; and then it has the extraordinary effect of preventing the action of the wind upon the water, ſo as to prevent the forming of waves. If a quantity of oil and water be put into a glaſs veſſel and ſwung, the ſurface of the water below the oil will be ſeen to change with reſpect to the veſſel, but not that of the oil. If ſpirit of wine be put upon them, that will be at reſt, and both the lower fluids in motion.

Vegetable oil is of two kinds, the *ſoft*, or *mild*, which has little or no taſte or ſmell, and the *eſſential* oil, which is thin, and retains the ſmell and taſte of the plant from which it was extracted.

Mild or ſweet oil is expreſſed from the grains or kernels of vegetables, and requires a conſiderable degree of heat to convert it into vapour, in which ſtate alone it is capable of being inflamed.

Eſſential oil is volatile in the heat of boiling water, and is generally obtained by means of diſtillation from the moſt odoriferous ſorts of plants; but is ſometimes found in their veſicles, as in the rind of an orange. The ſtrong taſte of this kind of oil ariſes from the diſengaged acid which abounds in it; and by this means it is ſoluble in ſpirit of wine, which ſweet oil is not: but it loſes much of this property by repeated diſtillations. By long expoſure to the air it loſes its more volatile parts, and thereby approaches to the nature of a reſin. This volatile odoriferous principle has been called the *ſpiritus rector* of the plant.

The eſſential oils of different plants differ much in their ſpecific gravity, and alſo in the manner by which they are affected by cold, ſome being heavier and others lighter than water, and ſome being more difficultly, and others more eaſily, congealed. Though the differences with reſpect to *weight* and *conſiſtency* in theſe oils is probably owing to the ſtate of the acid that is combined with them, theſe two properties are wholly independent of each other; ſome eſſential oils being very thin and yet heavy, and others thick and yet light. Eſſential oils are uſed in perfumes, and alſo in medicine, acting powerfully on the nervous ſyſtem.

Eſſential oils are very apt to be adulterated. If it be with ſweet oil, it may be diſcovered by evaporation on white paper, or by a ſolution in ſpirit of wine, which will not act upon the ſweet oil. If ſpirit of wine be mixed with it, it will be diſcovered by a milky appearance upon putting water to it, which uniting with the ſpirit, will leave the oil much divided. If oil of turpentine, which is the cheapeſt of eſſential oils, be mixed with any of the more valuable kinds, it will be diſcovered by evaporation; a ſtrong ſmell of turpentine being left on the paper, or cloth, upon which the evaporation was made.

Animal oil, like the vegetable, is of two kinds; the firſt *butter*, or *fat*, which is eaſily congealed, owing to the quantity of acid that is intimately combined with it. It reſembles the ſweet oil of vegetables in having no ſmell or taſte. The other kind of animal oil is extracted by diſtillation from the fleſh, the tendons, the bones, and horns, &c. of animals. It differs eſſentially from the other kind of animal oil, by containing an alkali inſtead of an acid. By repeated diſtillation it becomes highly attenuated and volatile; and in this ſtate it is called the *oil of Dippel*, the diſcoverer of it.

All oil expoſed to much heat is in part decompoſed, and acquires a diſagreeable ſmell; and in this ſtate it is ſaid to be *empyreumatic*: but this property is loſt by repeated diſtillations.

Beſides the vegetable and animal oils above deſcribed, there is a foſſil oil called *bitumen*, the ſeveral kinds of which differ much in colour and conſiſtence; the moſt liquid is called *petroleum*, from being found in the cavities of rocks, and the more ſolid kinds are *amber*, *jet*, *aſphaltum*, and *pit-coal*. When diſtilled, the principal component parts of all theſe ſubſtances are an oil and an acid. But all foſſil oil is probably of vegetable or animal origin, from maſſes of vegetables or animals long buried in the earth. Their differences from reſins and other oily matters are probably owing to *time*; the combinations of mineral acids and oils ſo nearly reſembling bitumens, the principal difference being their inſolubility in ſpirit of wine.

That the moſt ſolid of theſe, as amber,

has been formerly in a liquid ſtate, is evident, from inſects and other ſubſtances being frequently found in them; and pit-coal has been often found with both the internal texture and external appearance of wood; ſo that ſtrata of pit-coal have probably been beds of peat in ſome former ſtate of the earth.

LECTURE XIX.

Of Solid Subſtances.

ALL ſolid ſubſtances are capable of becoming fluid by heat, and moſt of them may thereby be reduced into a ſtate of vapour, or air; and in paſſing from a fluid into a ſolid ſtate their component parts aſſume a particular mode of arrangement, called *cryſtallization*, which differs according to the nature of the ſubſtance; ſo that all ſolids, eſpecially if they be ſuffered to concrete ſlowly, may be called *cryſtals*.

Excluſive of *ſalts*, which have been conſidered already, as formed by the union of acids and alkalis, ſolids in general have obtained the names of *earths*, or *ſtones*, which differ only in their texture; and they are diſtinguiſhed into thoſe that are *metallizable*, or thoſe that are not; the former being called *ores*, and the latter ſimply *earths*; the principal of which are the *calcareous*, *ſiliceous*, *argillaceous*, *magneſia*, *terra ponderoſa*, and a few others which have been diſcovered lately, but have not been much examined.

Of Calcareous Earth.

CALCAREOUS earth is found in the ſhells of fiſhes, the bones of animals, chalk, limeſtone, marble, and gypſum: but all calcareous earth is ſuppoſed to be of animal origin; and beds of chalk, lime-ſtone, or marble, are thought to have been beds of ſhells formed in the ſea, in ſome priſtine ſtate of the earth.

The calcareous earth which is found in

ſhells, lime-ſtone, and marble, is combined with fixed air, diſcovered by efferveſcing with acids. To obtain it perfectly pure, the earth muſt be pounded and waſhed with water, in order to free it from any ſaline ſubſtance which may be contained in it, then diſſolved in diſtilled vinegar, and precipitated by mild alkalies. Lime-ſtone expoſed to heat loſes about half its weight, in fixed air and water, and the remainder, called *quick-lime*, attracts water very powerfully, and their union is attended with much heat, after which it diſſolves into a fine powder called *ſlaked lime.* If it be left expoſed to the atmoſphere, it will of itſelf, by gradually imbibing moiſture, fall into the ſtate of powder.

Water diſſolves about one ſeven hundreth part of its weight of quick-lime, and is then called *lime-water*. Expoſed to the air, a cruſt will be formed on its ſurface, which is found to conſiſt of calcareous earth and fixed air.

Lime and water mixed with ſand make *mortar*, by which means different ſtones may be made to cohere as one maſs, which is the moſt valuable uſe of this kind of earth.

Calcareous earth, united with vitriolic acid, makes *gypſum*; and this ſubſtance pounded and expoſed to heat, parts with its water, and is then called *plaiſter of Paris.* In this ſtate, by imbibing water again, it becomes a firm ſubſtance, and thus is uſeful in making moulds, &c.

The earth of animal bones is calcareous united to the phoſphoric acid.

Of Siliceous Earth.

Siliceous earth ſeems to be formed by nature from chalk, perhaps by the introduction of ſome unknown acid, which the vitriolic acid is not able to diſlodge. It abounds in moſt ſubſtances which are hard enough to ſtrike fire with ſteel, as *flint*, *rock cryſtal*, and moſt *precious ſtones.* It is not acted upon by any acid except the fluor and phoſphoric, but eſpecially the former: but it is ſoluble in alkalies; and being then diſſolved in water, makes *liquor ſilicum*, from which the pureſt ſiliceous earth may be precipitated by acids. For this purpoſe about four times the weight of alkali muſt be made uſe of. With about equal weights of alkali and ſiliceous ſand is made *glaſs*, of ſo great uſe in admitting light and excluding the weather from our houſes, as well as for making various uſeful utenſils. To make glaſs perfectly colourleſs, and at the ſame time more denſe, commonly called *flint glaſs*, manufacturers uſe a certain proportion of calx of lead and manganeſe.

Siliceous earth is not affected by the ſtrongeſt heat, except by means of a burning lens, or dephlogiſticated air.

LECTURE

LECTURE XX.

Of Argillaceous Earth.

ARGILLACEOUS earth is found in *clay*, *ſchiſtus*, or *ſlate*, and in *mica*; but the pureſt is that which is precipitated from a ſolution of alum by alkalies; for alum conſiſts of the union of vitriolic acid and argillaceous earth.

This ſpecies of earth is ductile with water; it then hardens and contracts by heat, ſo as to be of the greateſt uſe in forming *bricks*, or ſtones of any required form or ſize. By means of the property of clay to contract in the fire, Mr. Wedgwood has conſtructed an excellent thermometer to meaſure the degrees of extreme heat.

The ductility of clay ſeems to depend upon ſome acid, probably the vitriolic, adhering to it; for it loſes that property when it is burned into a brick, but recovers it when it has been again diſſolved in an acid.

Of *Terra Ponderoſa*.

Terra ponderoſa, or *marmor metallicum*, is generally found in two ſtates, viz. united to vitriolic acid, when it is called *calk*, or to fixed air, when it is called *terra ponderoſa aerata*.

To obtain it pure from its union with the vitriolic acid, it muſt be melted with about twice its weight of fixed alkali; which unites with the acid, and forming a ſaline ſubſtance, may be waſhed out of it. In this ſtate it contains water, and therefore, when expoſed to heat, will yield fixed air; whereas the terra ponderoſa aerata will not yield fixed air by heat only, but when ſteam is made to paſs over it when red hot. This proves that water is eſſential to the compoſition of fixed air.

This ſtone is diſtinguiſhable by its great ſpecific gravity, being four times as heavy as water; but though in this it reſembles an *ore*, it has not been found to be metallizable.

Of Magneſia.

THIS ſpecies of earth is found in *ſteatites*, or *ſoap rock*, *Spaniſh chalk*, *aſbeſtus*, and *Muſcovy talck*; but the pureſt is got by diſſolving *Epſom ſalt* (which conſiſts of this earth united to the vitriolic acid) and precipitating it by a mild alkali. In this ſtate it becomes united to fixed air, which may be expelled by heat. It is then *calcined*, or *cauſtic*, but differs from quick-lime by not being ſoluble in water.

Aſbeſtus, which contains much of this kind of earth, is remarkable for not being deſtructible by heat, though it is ſometimes found in flexible fibres, ſo as to be capable of being woven into cloth.

Muſcovy talck is remarkable for the thin and tranſparent flakes into which it is diviſible, and thereby capable of various uſes.

There are ſome other diſtinct ſpecies of earth, particularly one brought from Botany Bay, and another called *Stontiate*, from the place where it was found in Scotland; but they have not as yet been much examined.

All ſtones formed by nature are compounded, and to diſtinguiſh them from one another, and aſcertain the parts of which they conſiſt, is the ſubject of *lithology*, a very extenſive branch of knowledge.

All the ſimple earths are nearly, if not abſolutely, *infuſible*; but when they are mixed they may all be fuſed.

LECTURE XXI.

Of Ores.

METALLIZABLE earths, commonly called *ores*, when united to phlogiſton, make the metals, diſtinguiſhable for their ſpecific gravity, their opacity, ſhining appearance, and fuſibility.

All the proper metals are *malleable*, and thoſe which are not ſo are called *ſemimetals*.

The metals again are ſubdivided into the *perfect* and *imperfect*. The former, which are *gold*, *ſilver*, and *platina*, ſuffer no change by fuſion, or the longeſt continued heat: whereas heat calcines or diſſipates the phlogiſton of the imperfect metals, which are *mercury*, *lead*, *copper*, *iron*, and *tin*, ſo that they return to the ſtate of earth; and this earth is always heavier than the metal, though of leſs ſpecific gravity, having received an addition of weight from water or air: but theſe earths, or ores, being expoſed to heat in contact with ſubſtances containing phlogiſton, again become metals, and are then ſaid to be *revived*.

The ſemi-metals are *biſmuth*, *zinc*, *nickel*, regulus of *arſenic*, of *cobalt*, of *antimony*, of *mangane ſe*, of *wolfram*, and of *molybdena*.

All metallic ſubſtances are cryſtallizable, and each in a peculiar form, which is diſcovered by leaving a hole in the bottom of the crucible in which they are melted, and drawing out the ſtopper, when the maſs is beginning to loſe its fluidity.

Some of the metals will not unite to others when hot, and others of them will;

and ſuch as will unite with others are called *ſolders*. Thus tin is a ſolder for lead, and braſs, gold, or ſilver, for iron.

Ores are never found in regular ſtrata, like the different kinds of earth; but in places which have formerly been cavities, running in all directions, with reſpect to the regular ſtrata, and commonly called *veins*.

Many of the ores in their natural ſtate are ſaid to be *mineralized* with arſenic or ſulphur, thoſe ſubſtances being intimately united with the metallic earths.

In order to convert the ores into metals, ſome of them are firſt reduced to powder, to waſh out the earthy or ſaline particles. They are then kept in a red heat, which the workmen call *roaſting*, in order to drive away the arſenic, or ſulphur, which are volatile; and in the laſt place they are fuſed in contact with charcoal, or other ſubſtances containing phlogiſton; and to promote the fuſion, lime-ſtone is frequently mixed with them. When the operation is completed, the unmetallic parts are converted into glaſs, or *ſcoria*, which lies on the ſurface, whereas the metal is found at the bottom.

To diſcover the quantity of metal in a ſmall piece of ore is called *aſſaying*.

When metals are fuſed together, the ſpecific gravity, fuſibility, and other properties are changed, and in ſuch a manner as could not be diſcovered from the properties of the conſtituent parts.

Of Gold.

GOLD is the heavieſt of all metallic bodies except platina. It appears yellow or reddiſh by reflected light, but green or blue by tranſmitted light, when it is reduced to thin plates.

Though gold undergoes no change in a common furnace, or burning lens, it may, in part, at leaſt, be calcined by the electric ſhock.

Gold has the greateſt *ductility*, and in wires of equal diameters, it has the greateſt *tenacity*, of all the metals. One grain of it may be made to cover 56 ſquare inches; ſome gold leaf being leſs than a 200,000th part of an inch thick; and when it is made to cover a ſilver wire, the gold upon it may not be more than one twelfth part of the thickneſs of the gold leaf.

This metal is ſoluble in aqua regia; and being precipitated by a volatile alkali, makes a powder called *aurum fulminans*, which is one fourth heavier than the gold, and explodes with great violence in a heat ſomething greater than that of boiling water.

Tin precipitates gold in the form of a purple powder, called the *powder of Caſſius*, from the inventor of it, and is uſed in enamels, or the glaſſy coating which is given to metals by heat.

Gold unites with moſt of the metals, eſpecially with mercury, and theſe mixtures are called *amalgams*. In gilding, the amalgam is applied to the ſurface of the metal to be gilded, and the mercury is driven off by heat, leaving the gold attached to the ſurface.

Gold mixed with iron, makes it harder, for the purpoſe of cutting inſtruments.

To ſeparate gold from the imperfect metals, ſuch as copper, &c. it is mixed with lead, and then expoſed to a ſtrong heat, which calcines the lead, and with it the imperfect metals, leaving the gold pure. This proceſs is called *cupellation*, from being performed in a ſmall crucible called a *cupell.* When the gold is mixed with ſilver, three parts more of ſilver are put to it, and then the ſilver is diſſolved by nitrous acid, leaving the gold pure. This proceſs is called *quartation*, from the gold being one fourth part of the maſs.

The fineneſs of gold is generally eſtimated by dividing the gold into twenty-four parts, called *carats.* The phraſe *twenty-three carats fine* means that the maſs contains twenty-three parts out of twenty-four of pure gold, the remainder being *alloy*, of ſome baſer metal. The fineneſs of gold may in ſome meaſure be diſcovered by the colour it leaves upon a *touch-ſtone*, or fine-grained baſaltes.

Gold is generally found nearly pure, but mixed with earth, or diffuſed in fine grains through ſtones.

LECTURE XXII.

Of Silver.

SILVER is the whiteſt of all the metals, very ductile, but leſs ſo than gold; the thinneſt leaves of it being one third thicker than thoſe of gold. It is not calcined in the heat of a common furnace, but partially ſo by repeated fuſion, or a ſtrong burning lens.

Sulphureous fumes unite with ſilver, and tinge it black. The nitrous acid diſſolves it, and will hold more than half its weight of it in ſolution. When fully ſaturated, this ſolution depoſits cryſtals, which are called *lunar nitre*, or *nitre of ſilver*. When theſe cryſtals are melted, and the water they contain driven off, a black ſubſtance, called *lapis infernalis*, or *lunar cauſtic*, is formed. This is uſed as a cautery in ſurgery. A ſtrong heat will decompoſe this lunar nitre, and recover the ſilver.

Though the nitrous acid diſſolves ſilver the moſt readily, the marine acid will deprive the nitrous of it, and form a ſubſtance called *luna cornea*, becauſe, when it is melted and cold, it becomes a tranſparent maſs ſomething reſembling *horn*. From this luna cornea the pureſt ſilver may be obtained. The vitriolic acid will likewiſe deprive the nitrous of the ſilver contained in it, and form a white powder, not eaſily ſoluble in water.

A fulminating ſilver may be made by the following proceſs: the ſilver muſt firſt be diſſolved in pale nitrous acid, then precipitated by lime-water, dried, and expoſed to the air three days. It muſt then be waſhed in cauſtic volatile alkali, after which the fluid muſt be decanted, and the black powder left to dry in the air. The ſlighteſt friction will cauſe this powder to fulminate. It is ſaid, that even a drop of water falling upon it will produce this effect; ſo that it ought to be made only in very ſmall quantities, and managed with the greateſt caution.

Moſt of the metals precipitate ſilver. That by mercury may be made to aſſume the form of a tree, called *arbor Dianæ*.

Silver is found native in Peru; and the ores frequently contain ſulphur, or arſenic, or both.

Of Platina.

PLATINA is a metal lately diſcovered in the gold mines of Mexico, where it is found in ſmall particles, never exceeding the ſize of a pea, mixed with ferruginous ſand and quartz.

The ſtrongeſt fire will not melt theſe grains, though it will make them cohere; but they may be melted by a burning lens, or a blow-pipe ſupplied with dephlogiſticated air.

Pure platina is the heavieſt body in nature, its ſpecific gravity exceeding twenty-two. It is very malleable, though conſiderably harder than gold or ſilver, and has the property of welding in common with iron. This metal is not affected by expoſure to the air, or by any ſimple acid, though concentrated and hot; but it is diſſolved by dephlogiſticated marine acid, and by aqua regia, in which a little nitrous air is procured. The ſolution is brown, and when diluted yellow. This liquor is very corroſive, and tinges animal ſubſtances of a blackiſh brown colour. Platina is precipitated from a ſolution in aqua regia by ſal-ammoniac, as gold is by martial vitriol. Iron is precipitated from this ſolution by the Pruſſian alkali. Alſo moſt of the metals precipitate platina, but not in its metallic ſtate.

Arſenic facilitates the ſolution of platina; and by melting it with equal parts of arſenic and vegetable alkali, and then reducing the maſs to a powder, it may be made to take any form; and a ſtrong heat will diſſipate the arſenic and the alkali, leaving the platina in the ſhape required, not fuſible by any heat in a common furnace.

Platina does not readily combine with gold or ſilver, and it reſiſts the action of mercury as much as iron; but it mixes well with lead, making it leſs ductile, and even brittle, according to the proportion of the platina. With copper it forms a compound which takes a beautiful poliſh, not liable to tarniſh, and is therefore uſed with advantage for mirrors of reflecting teleſcopes. It unites eaſily with tin, and alſo with biſmuth, antimony, and zinc.

LECTURE XXIII.

Of Mercury.

MERCURY is the moſt fuſible of all the metals, not becoming ſolid but in 40° below 0 in Fahrenheit's thermometer. It is then malleable. It is heavier than any other metal except gold or platina. It is volatile in a temperature much lower than that of boiling water, and in vacuo in the common temperature of the atmoſphere; and at ſix hundred it boils.

In a degree of heat in which it would riſe eaſily in vapour, mercury imbibes pure air, and becomes a red calx, called *precipitate per ſe.* At a greater degree of heat it parts with that air, and is running mercury again.

Mercury is not perceptibly altered by expoſure to the air.

Mercury is acted upon by the vitriolic acid when hot. In this proceſs vitriolic acid air is procured, and the mercury is converted into a white ſubſtance, which being dipped in water becomes yellow, called *turbith mineral*, one third heavier than the mercury from which it was made. By heat this ſubſtance parts with its pure air, and becomes running mercury; but if the proceſs be made in a clean earthen veſſel, there will remain a portion of *red calx*, which cannot be reduced by any degree of heat, except in contact with ſome ſubſtance containing phlogiſton. If this be done with a burning lens, in inflammable air, much of the air will be abſorbed.

Mercury is diſſolved moſt readily in the nitrous acid, when the pureſt nitrous air is procured; and there remains a ſubſtance which is firſt yellow, and by continuance red, called *red precipitate*. In a greater degree of heat the dephlogiſticated air will be recovered, and the mercury be revived; but the ſubſtance yields nitrous air after it becomes ſolid, and till it changes from yellow to red.

The precipitates of mercury from acids by means of alkalies poſſeſs the property of exploding, when they are expoſed to a gradual heat in an iron ſpoon, after having been triturated with one ſixth of their weight of the flowers of ſulphur. The reſiduum conſiſts of a violet-coloured powder, which, by ſublimation, is converted into cinnabar.

It ſeems, therefore, as if the ſulphur combined ſuddenly with the mercury, and expelled the dephlogiſticated air in an elaſtic ſtate.

The marine acid ſeizes upon mercury diſſolved in nitrous acid, and if the acid be dephlogiſticated, the precipitate is *corroſive ſublimate*;

limate; but with common marine acid, it is called *calomel*, or *mercurius dulcis*. This preparation is generally made in the dry way, by triturating equal parts of mercury, common ſalt and vitriol, and expoſing the whole to a moderate heat; when the corroſive ſublimate riſes, and adheres to the upper part of the glaſs veſſel in which the proceſs is made.

Mercury combines readily with ſulphur by trituration, and with it forms a black powder called *Ethiops mineral.* A more intimate combination of mercury and ſulphur is made by means of fire. This is called *cinnabar*, about one third of which is ſulphur. Vermillion is cinnabar reduced to powder.

Mercury readily unites with oil, and with it forms a deep black or blue compound, uſed in medicine.

It readily combines with moſt of the metals, and when it is uſed in a ſufficient quantity to make them ſoft, the mixture is called an *amalgam*. It combines moſt readily with gold, ſilver, lead, tin, biſmuth, and zinc. Looking-glaſſes are covered on the back with an amalgam of mercury and tin.

When mercury is united with lead or other metals, it is rendered leſs brilliant and leſs fluid; but agitation in pure air converts the impure metal into a calx, together with much of the mercury, in the form of a black powder.

Heat recovers the pure air, and the mercury, leaving the calx of the impure metal.

Much mercury is found native in a ſlaty kind of earth, or in maſſes of clay or ſtone; but the greateſt quantity is found combined with ſulphur in *native cinnabar*.

LECTURE XXIV.

Of Lead.

LEAD is a metal of a bluiſh tinge, of no great tenacity, but very conſiderable ſpecific gravity, being heavier than ſilver. It melts long before it is red hot, and is then calcined, if it be in contact with reſpirable air. When boiling it emits fumes, and calcines very rapidly. It may be granulated by being poured into a wooden box, and agitated. During congelation it is brittle, ſo that the parts will ſeparate by the ſtroke of a hammer; and by this means the form of its cryſtals may be diſcovered.

In the progreſs of calcination it firſt becomes a duſky grey powder, then yellow, when it is called *maſſicot*; then, by imbibing pure air, it becomes red, and is called *minium*, or *red lead.* In a greater degree of heat it becomes maſſicot again, having parted with its pure air. If the heat be too great, and applied rapidly, it becomes a flaky ſubſtance, called *litharge*; and with more heat it becomes a *glaſs*, which readily unites with metallic calces and earths, and is a principal ingredient in the manufacture of *flint glaſs*, giving it its peculiar denſity and refractive power.

Though lead ſoon tarniſhes, the imperfect calx thus made does not ſeparate from the reſt of the metal, and therefore protects it from any farther action of the air, by which means it is very uſeful for the covering of houſes, and other ſimilar purpoſes. All acids act upon lead, and form with it different ſaline ſubſtances. *White-lead* conſiſts of its union with vinegar and pure air. Alſo diſſolved in vinegar, and cryſtallized, it becomes *ſugar of lead*, which, like all the other preparations of this metal, is a deadly poiſon.

Oils diſſolve the calces of lead, which, by this means, is the baſis of paints, plaiſters, &c.

By means of heat litharge decompoſes common ſalt, the lead uniting with the marine acid, and forming a yellow ſubſtance,

ſtance, uſed in painting, and by this means the foſſil alkali is ſeparated.

Lead unites with moſt metals, though not with iron. Two parts of lead and one of tin make a *ſolder*, which melts with leſs heat than either of the metals ſeparately; but a compoſition of eight parts of biſmuth, five of lead, and three of tin, makes a metal which melts in boiling water.

This metal will be diſſolved by water if it contain any ſaline matter, and the drinking of it occaſions a peculiar kind of cholic.

Lead is ſometimes found native, but generally minerally mineralized with ſulphur or arſenic, and often mixed with a ſmall quantity of ſilver.

Of Copper.

COPPER is a metal of a reddiſh or browniſh colour, conſiderably ſonorous, and very malleable.

At a heat far below ignition, the ſurface of copper becomes covered with a range of priſmatic colours, the commencement of its calcination; and with more heat a black ſcale is formed, which eaſily ſeparates from the metal, and in a ſtrong heat it melts, and burns with a bluiſh green flame.

Copper ruſts by expoſure to the air; but the partially-calcined ſurface adheres to the metal, as in the caſe of lead, and thus preſerves it from farther corroſion.

Copper diſſolved in the vitriolic acid forms cryſtals of a blue colour, called *blue copperas*. From this ſolution it is precipitated by iron, which by this means becomes coated with copper. The nitrous acid diſſolves copper with moſt rapidity, producing nitrous air. If the ſolution be diſtilled, almoſt all the acid will be retained in the reſiduum, which is white; but more heat will expel the acid, chiefly in the form of dephlogiſticated air, and the remainder will be a black ſubſtance, conſiſting of the pure calx of copper. The vegetable acids diſſolve copper as well as the mineral ones, which makes the uſe of this metal for culinary purpoſes in ſome caſes dangerous.

To prevent this they give it a coat of tin. The ſolution of copper in the vegetable acid is called *verdigris*.

Alkalies diſſolve copper as well as acids. With the volatile alkali a blue liquor is formed, but in ſome caſes it becomes colourleſs. All the circumſtances of this change of colour have not yet been examined. Both oil and ſulphur will diſſolve copper, and with the latter it forms a blackiſh grey compound, uſed by dyers.

Copper readily unites with melted tin, at a temperature much lower than that which is neceſſary to melt the copper; by which means copper veſſels are eaſily covered with a coating of tin. A mixture of copper and tin, called *bronze*, the ſpecific gravity of which is greater than that of the medium of the two metals, is uſed in caſting ſtatues, cannon, and bells; and in a certain proportion this mixture is excellent for the purpoſe of mirrors of reflecting teleſcopes, receiving a fine poliſh, and not being apt to tarniſh. Copper and arſenic make a brittle compound called *tombach*;

and with zinc it makes the uſeful compound commonly called *braſs*, in which zinc is about one third of its weight.

Copper is ſometimes found native; but commonly mixed with ſulphur, in ores of a red, green, or blue colour.

Copper being an earlier diſcovery than that of iron, was formerly uſed for weapons and the ſhoeing of horſes; and the ancients had a method, with which we are not well acquainted, of giving it a conſiderable degree of hardneſs, ſo that a ſword made of it might have a pretty good edge.

LECTURE XXV.

Of Iron.

IRON is a metal of a bluiſh colour, of the greateſt hardneſs, the moſt variable in its properties, and the moſt uſeful of all the metals; ſo that without it it is hardly poſſible for any people to make great advances in arts and civilization.

This metal readily parts with its phlogiſton, ſo as to be very ſubject to calcine, or ruſt, by expoſure to the air. The ſame is evident by the colours which appear on its ſurface when expoſed to heat, and alſo when it is ſtruck with flint; the particles that fly from it being iron partially calcined. In conſequence of its readily parting with its phlogiſton, it is capable of burning, like wood or other fuel, in pure air.

Iron and platina have the property of *welding* when very hot, ſo that two pieces may be joined without any ſolder.

When iron is heated in contact with ſteam, part of the water takes the place of the phlogiſton, while the reſt unites with it, and makes inflammable air. By this means the iron acquires one third more weight, and becomes what is called *finery cinder*. This ſubſtance, heated in inflammable air, imbibes it, parts with its water, and becomes perfect iron again. If the iron be heated in pure air, it alſo imbibes the water, of which that air chiefly conſiſts, and alſo a portion of the peculiar element of the pure air.

The ſolution of iron in ſpirit of vitriol produces *green copperas*; which being calcined, becomes a red ſubſtance, called *colcothar*.

The precipitate of iron, by an infuſion of galls, is the colouring matter in *ink*, which is kept ſuſpended by means of gum. The precipitate from the ſame ſolution by phlogiſticated alkali, is *Pruſſian blue*.

Water ſaturated with fixed air diſſolves iron, and makes a pleaſant chalybeat.

The calx of iron gives a green colour to glaſs.

Iron readily combines with ſulphur. When they are found combined by nature, the ſubſtance is called *pyrites*.

The union of phoſphoric acid with iron makes it brittle when cold, commonly called *cold ſhort*; and the union of arſenic makes it brittle when hot, thence called *red ſhort*.

Iron unites with gold, ſilver, and platina, and plunged in a white heat into mercury, it becomes coated with it; and if the proceſs be frequently repeated, it will become brittle, which ſhews that there is ſome mutual action between them.

Iron readily unites with tin; and by dipping thin plates of iron into melted tin, they get a complete coating of it, and make the *tinned plates* in common uſe.

When crude iron comes from the ſmelting furnace it is brittle; and when it is white within, it is extremely hard; but when it has a black grain, owing to its having more phlogiſton, it is ſofter, and may be filed and bored.

Caſt iron becomes *malleable* by being expoſed to a blaſt of air when nearly melting;

the conſequence of which is a diſcharge of inflammable air, and the ſeparation of a liquid ſubſtance, which, when concreted, is called *finery cinder*. The iron generally loſes one fourth of its weight in the proceſs. Crude iron contains much *plumbago*, and the acceſs of pure air probably aſſiſts in diſcharging it, by converting it into air, chiefly inflammable.

Malleable iron, expoſed to a red heat in contact with charcoal, called *cementation*, converts it into *ſteel*, which has the properties of becoming much harder than iron, and very elaſtic, by being firſt made very hot, and then ſuddenly cooled, by plunging it in cold water. By firſt making it very hard, and then giving different degrees of heat, and cooling it in thoſe different degrees, it is capable of a great variety of *tempers*, proper for different uſes. Of the degrees of heat workmen judge by the change of colour on its ſurface. Steel, like crude iron, is capable of being melted without loſing its properties. It is then called *caſt ſteel*, and is of a more uniform texture. Iron acquires ſome little weight by being converted into ſteel; and when diſſolved in acid, it yields more plumbago. Steel has ſomething leſs ſpecific gravity than iron. If the cementation be continued too long, the ſteel acquires a darkiſh fracture, it is more fuſible, and incapable of welding. Steel heated in contact with earthy matters, is reduced to iron.

Iron is the only ſubſtance capable of *magnetiſm*; and hardened ſteel alone is capable of retaining magnetiſm. The loadſtone is an ore of iron.

LECTURE XXVI.

Of Tin.

TIN is a metal of a ſlightly yellowiſh caſt, though harder than lead, very malleable, but of no great tenacity; ſo that wires cannot be made of it. It eaſily extends under the hammer, and plates of it, called *tinfoil*, are made only one thouſandth part of an inch thick, and might be made as thin again.

Tin has leſs ſpecific gravity than any other metal. It melts long before ignition, at 410 of Fahrenheit, and by the continuance of heat is ſlowly converted into a white powder, which is the chief ingredient in *putty*, uſed in poliſhing, &c. Like lead, it is brittle when heated a little ſhort of fuſion, and may be reduced into grains by agitation as it paſſes from a fluid to a ſolid ſtate.

The calx of tin reſiſts fuſion more than that of any other metal, which makes it uſeful in making an opaque white enamel.

Tin loſes its bright ſurface when expoſed to the air, but is not properly ſubject to ruſt; ſo that it is uſeful in protecting iron and other metals from the effects of the atmoſphere.

Concentrated vitriolic acid, aſſiſted by heat, diſſolves half its weight of tin, and yields vitriolic acid air. With more water it yields inflammable air. During the ſolution,

lution, the phlogiſton of the tin uniting with the acid, forms ſulphur, which makes it turbid. By long ſtanding, or the addition of water, the calx of tin is precipitated from the ſolution. The nitrous acid diſſolves tin very rapidly without heat, and yields but little nitrous air. With marine acid this metal yields inflammable air. With aqua regia it aſſumes the form of a gelatinous ſubſtance uſed by dyers to heighten the colour of ſome red tinctures, ſo as to produce a bright ſcarlet in dying wool.

A tranſparent liquor, which emits very copious fumes, called, from the inventor, *the ſmoking liquor of Libavius*, is made by diſtilling equal parts of amalgam of tin and mercury with corroſive ſublimate, triturated together. A colourleſs liquor comes over firſt, and then a thick white fume, which condenſes into the tranſparent liquor above mentioned. Mr. Adet has ſhewn, that this liquor bears the ſame relation to the common ſolution of tin, that corroſive ſublimate does to calomel, and has given an ingenious ſolution of many of its properties.

Tin detonates with nitre; and if the cryſtals made by the ſolution of copper in the nitrous acid be incloſed in tinfoil, nitrous fumes will be emitted, and the whole will become red hot. Alſo if five times its weight of ſulphur be added to melted tin, a black brittle compound, which readily takes fire, will be formed.

Another combination of tin, ſulphur, and mercury, makes a light yellow ſubſtance, called *aurum muſivum*, uſed in painting.

Tin is the principal ingredient in the compoſition of *pewter*, the other ingredients being lead, zinc, biſmuth, and copper, each pewterer having his peculiar receipt. It is alſo uſed in coating copper and iron plates, and in ſilvering looking-glaſſes, beſides being caſt into a variety of forms, when it is called *block tin*.

Tin is ſometimes found native, but is generally mineralized with ſulphur and arſenic. The latter is thought to be always contained in tin, and to be the cauſe of the crackling noiſe made by bending plates of it.

Of the Semi-metals.

Bismuth is a ſemi-metal of a yellowiſh or reddiſh caſt, but little ſubject to change in the air, harder than lead, but eaſily broken, and reducible to powder. When broken it exhibits large ſhining facets, in a variety of poſitions. Thin pieces of it are conſiderably ſonorous.

Biſmuth melts at about 460° of Fahrenheit. With more heat it ignates, and burns with a ſlight blue flame, while a yellowiſh calx, called *flowers of biſmuth*, is produced. With more heat it becomes a greeniſh glaſs. In a ſtrong heat, and in cloſe veſſels, this metal ſublimes.

Vitriolic acid, even concentrated and boiling, has but little effect upon biſmuth; but the nitrous acid acts upon it with the greateſt rapidity and violence, producing much nitrous air, mixed with phlogiſticated nitrous vapour. From the ſolution of biſmuth in this acid, a white ſubſtance, called *magiſtery of biſmuth*, is precipitated by the affuſion of water. This has been uſed as a paint for the ſkin, but has been thought to injure it.

The marine acid does not readily act upon biſmuth; but when concentrated, it forms with it a ſaline combination, which does not eaſily cryſtallize, but may be ſublimed in the form of a ſoft fuſible ſalt, called *butter of biſmuth.*

Biſmuth unites with moſt metallic ſubſtances, and in general renders them more fuſible. When calcined with the imperfect metals, it unites with them, and has the ſame effect as lead in cupellation.

Biſmuth is uſed in the compoſition of pewter, in printers' types, and other metallic mixtures.

This metal is ſometimes found native, but more commonly mineralized with ſulphur.

LECTURE XXVII.

Of Nickel.

NICKEL is a ſemi-metal of a reddiſh caſt, of great hardneſs, and always magnetical; on which account it is ſuppoſed to contain iron, though chemiſts have not yet been able to ſeparate them.

The pureſt nickel was ſo infuſible as not to run into a maſs in the ſtrongeſt heat of a ſmith's forge; but then it was in ſome degree malleable.

Concentrated acid of vitriol only corrodes nickel. Alkalies precipitate it from its ſolution in the nitrous acid, and diſſolve the precipitate. It readily unites with ſulphur.

Nickel is found either native or mineralized with ſeveral other metals, eſpecially with copper, when it is called *kupfer nickel*, or *falſe copper*, being of a reddiſh or copper colour.

This ſemi-metal has not yet been applied to any uſe.

Of Arſenic.

WHAT is commonly called *arſenic* is the calx of a ſemi-metal called the *regulus of arſenic.* It is a white and brittle ſubſtance, expelled from the ores of ſeveral metals by heat. It is then refined by a ſecond ſublimation, and melted into the maſſes in which it is commonly ſold. This calx is ſoluble in about eighty times its weight of cold water, or in fifteen times its weight of boiling water. It acts in many reſpects like an acid, as it decompoſes nitre by diſtillation, when the nitrous acid flies off, and the *arſenical ſalt of Macquer* remains behind.

When the calx of arſenic is diſtilled with ſulphur, the vitriolic acid flies off, and a ſubſtance of a yellow colour, called *orpiment*, is produced. This appears to conſiſt of ſulphur and the regulus of arſenic; part of the ſulphur receiving pure air from the calx, to which it communicates phlogiſton; and thus the ſulphur becomes converted into vitriolic acid, while the arſenical calx is reduced, and combines with the reſt of the ſulphur.

The combination of ſulphur and arſenic, by melting them together, is of a red colour, known by the name of *realgal*, or *realgar*. It is leſs volatile than orpiment.

The ſolution of fixed alkali diſſolves the calx of arſenic, and by means of heat a brown tenacious maſs is produced, and having alſo a diſagreeable ſmell, it is called *liver of arſenic*.

The regulus of arſenic is of a yellow colour, ſubject to tarniſh or grow black, by expoſure to the air, very brittle, and of a laminated texture. In cloſe veſſels it wholly ſublimes, but burns with a ſmall flame in pure air.

Vitriolic acid has little action upon this ſemi-metal, except when hot; but the nitrous acid acts readily upon it, and likewiſe diſſolves the calx, as does boiling marine acid, though it affects it very little when cold.

Moſt of the metals unite with the regulus of arſenic.

Dephlogiſticated marine acid converts the calx of arſenic into *arſenical acid* by giving it pure air.

The acid of arſenic acts more or leſs upon all metals, but the phenomena do not appear to be of much importance.

The calx of acid is uſed in a variety of the arts, eſpecially in the manufactory of glaſs. Orpiment and realgar are uſed as pigments. Some attempts have been made to introduce it into medicine, but being dangerous, the experiments ſhould be made with caution.

Of Cobalt.

Cobalt is a ſemi-metal of a grey or ſteel colour, of a cloſe-grained fracture, more difficult of fuſion than copper, not eaſily calcined. It ſoon tarniſhes in the air, but water has no effect upon it.

Cobalt, diſſolved in *aqua regia*, makes an excellent ſympathetic ink, appearing green when held to the fire, and diſappearing when cold, unleſs it has been heated too much, when it burns the paper.

The calx of cobalt is of a deep blue colour, which, when fuſed, makes the blue glaſs called *ſmalt.* The ore of cobalt, called *zaffre*, is found in ſeveral parts of Europe, but chiefly in Saxony. As it is commonly ſold, it contains twice or thrice its weight of powder of flints. The ſmalt is uſually compoſed of one part of calcined cobalt, fuſed with two parts of powder of flint and one of pot-aſh.

The chief uſe of cobalt is for making ſmalt; but the powder and the blue-ſtone uſed by laundreſſes is a preparation made by the Dutch of a coarſe kind of ſmalt.

Of Zinc.

ZINC is a ſemi-metal of a bluiſh caſt, brighter than lead, and ſo far malleable as not to be broken by a hammer, though it cannot be much extended. When broken by bending, it appears to conſiſt of cubical grains. If it be heated nearly to melting, it will be ſufficiently brittle to be pulverized. It melts long before ignition, and when it is red hot, it burns with a dazzling white flame, and is calcined with ſuch rapidity, that its calx flies up in the form of white flowers, called *flowers of zinc*, or *philoſophical wool*. In a ſtronger heat they become a clear yellow glaſs. Heated in cloſe veſſels, this metal riſes without decompoſition, being the moſt volatile of all the metals except the regulus of *arſenic*.

Zinc diſſolved in diluted vitriolic acid, yields much inflammable air, and has a reſiduum, which appears to be plumbago, and the liquor forms cryſtals, called *white copperas*. This metals alſo yields inflammable air when diſſolved in the marine acid. Diſſolved in the nitrous acid, it yields dephlogiſticated nitrous air, with very little proper nitrous air.

The ore of zinc, called *calamine*, is generally of a white colour; and the chief uſe of it is to unite it with copper, with which it makes braſs and other gold-coloured mixtures of metals. The calx and the ſalts of this metal are occaſionally uſed in medicine.

LECTURE XXVIII.

Of Antimony.

THE regulus of animony is of a ſilvery white colour, of a ſcaly texture, very brittle, and melts ſoon after ignition. By continuance of heat it calcines in white fumes, called *argentine flowers of antimony*, which melt into a hyacinthine glaſs. In cloſe veſſels it riſes without decompoſition. Its calx is ſoluble in water, like that of arſenic. This metal tarniſhes, but does not properly ruſt, by expoſure to the air.

This metal is ſoluble in aqua regia. It detonates with nitre, and what remains of equal parts of nitre and regulus of antimony after detonation, in a hot crucible, is called *diaphoretic antimony*. The water uſed in this preparation contains a portion of the calx ſuſpended by the alkali, and being precipitated by an acid, is called *ceruſe of antimony*.

When regulus of antimony is pulverized and mixed with twice its weight of corroſive ſublimate (which is attended with heat) and then diſtilled with a gentle fire, a thick fluid comes over, which is congealed in the receiver, or in the neck of the retort, and is called *butter of antimony*. The reſiduum conſiſts of revived mercury, with ſome regulus and calx of antimony. When this butter of antimony is thrown into pure water, there is a white precipitate, called *powder of algaroth*, a violent emetic. Nitrous acid diſſolves the butter of antimony; and when an equal weight of nitrous acid has been three times diſtilled to dryneſs from butter of antimony, the reſiduum, after ignition, is called *bezoar mineral*, and ſeems to be little more than a calx of the metal.

Crude antimony, which has been much uſed in the experiments of alchemiſts, is a combination of ſulphur and regulus of antimony. Heat melts it, and finally converts it into glaſs, of a dark red colour, called *liver of antimony*. If antimony be melted or boiled with a fixed alkali, a precipitate is made by cooling, called *kermes mineral*, formerly uſed in medicine. The antimonial preparations that are now moſt in uſe are *antimonial wine* and *tartar emetic*. The wine is made by infuſing pulverized glaſs of antimony in Spaniſh wine ſome days, and filtering the clear fluid through paper. The emetic tartar, or antimonial tartar, is a ſaline ſubſtance, compoſed of acid of tartar, vegetable alkali, and antimony partially calcined. The preparation may be ſeen in the Diſpenſaries.

The regulus of antimony is uſed in the form of pills, which purge more or leſs in proportion to the acid they meet with; and as they undergo little or no change in paſſing through the body, they are called *perpetual pills*.

Of Manganeſe.

MANGANESE is a hard, black mineral, very ponderous, and the regulus of it is a ſemi-metal of a dull white colour when broken, but ſoon grows dark by expoſure to the air. It is hard and brittle, though not pulverizable, rough in its fracture, and of very difficult fuſion. Its calces are white when imperfect, but black, or dark green, when perfect. The white calx is ſoluble in acids. When broken in pieces, it falls into powder by a ſpontaneous calcination, and this powder is magnetical, though the maſs was not poſſeſſed of that property. The black calx of manganeſe is altogether inſoluble in acids. It contains much dephlogiſticated air.

The calx of manganeſe is uſed in making glaſs; the glaſs deſtroying the colour of that of the other materials, and thereby making the whole maſs tranſparent.

This ſemi-metal mixes with moſt of the metals in fuſion, but not with mercury.

There is another ore of manganeſe, called *black woad*, which inflames ſpontaneouſly when mixed with oil.

Of Wolfram.

WOLFRAM is a mineral of a browniſh or black colour, found in the tin mines of

Cornwall, of a radiated or foliated texture, ſhining almoſt like a metal. It contains much of the calx of manganeſe, and iron; but when the ſubſtance is pulverized, theſe are eaſily diſſolved, and the calx of wolfram is found to be yellow.

This calx turns blue by expoſure to light; and an hundred grains of it heated with charcoal will yield ſixty grains of a peculiar metal, in ſmall particles, which, when broken, look like ſteel. It is ſoluble in the vitriolic or marine acids, and reduced to a yellow calx by nitrous acid or aqua regia.

Of Molybdena.

MOLYBDENA is a ſubſtance which much reſembles plumbago; but its texture is ſcaly, and not eaſily pulverized, on account of a degree of flexibility which its laminæ poſſeſs. With extreme heat, and mixed with charcoal, it yields ſmall particles of a metal that is grey, brittle, and extremely infuſible; and uniting with ſeveral of the metals, it forms with them brittle or friable compounds. By heat it is converted into a white calx.

Of Solid Combuſtible Subſtances.

There yet remains a claſs of ſolid ſubſtances, of the *combuſtible* kind, but moſt of them have been already conſidered under the form of the fluids, from which they are originally formed, as *bitumen*, *pit-coal*, and *amber*; or under the principal ingredients of which they are compoſed, as *ſulphur* and *plumbago*.

There only remains to be mentioned the *diamond*, which is of a nature quite different from that of the other precious ſtones, the principal ingredient in which is ſiliceous earth, which renders them not liable to be much affected by heat. On the contrary, the diamond is a combuſtible ſubſtance; for in a degree of heat ſomewhat greater than that which will melt ſilver, it burns with a ſlight flame, diminiſhes common air, and leaves a ſoot behind. Alſo, if diamond powder be triturated with vitriolic acid, it turns it black, which is another proof of its containing phlogiſton.

The diamond is valued on account of its extreme hardneſs, the exquiſite poliſh it is capable of, and its extraordinary refractive power; for light falling on its interior ſurface with an angle of incidence greater than 24½ will be wholly reflected, whereas in glaſs it requires an angle of 41 degrees.

LECTURE XXIX.

Of the Doctrine of Phlogiſton and the Compoſition of Water.

IT was ſuppoſed to be a great diſcovery of Mr. Stahl, that all inflammable ſubſtances, as well as metals, contain a principle, or ſubſtance, to which he gave the name of phlogiſton, and that the addition or deprivation of this ſubſtance makes ſome of the moſt remarkable changes in bodies, eſpecially that the union of a metallic calx and this ſubſtance makes a metal; and that combuſtion conſiſts in the ſeparation of phlogiſton from the ſubſtances that contain it. That it is the ſame principle, or ſubſtance, that enters into all inflammable ſubſtances, and metals, is evident, from its being diſengaged from any of them, and entering into the compoſition of any of the others. Thus the phlogiſton of charcoal or inflammable air becomes the phlogiſton of any of the metals, when the calx is heated in contact with either of them.

On the contrary, Mr. Lavoiſier and moſt of the French chemiſts, are of opinion, that there is no ſuch principle, or ſubſtance, as phlogiſton; that metals and other inflammable bodies are ſimple ſubſtances, which have an affinity to pure air; and that combuſtion conſiſts not in the ſeparation of any thing from the inflammable ſubſtance, but in the union of pure air with it.

They moreover ſay, that water is not, as has been commonly ſuppoſed, a ſimple ſubſtance, but that it conſiſts of two elements, viz. pure air, or *oxygene*, and another, to which they give the name of *hydrogene*, which, with the principle of *heat*, called by them *calorique*, is inflammable air.

The principal fact adduced by them to prove that metals do not loſe any thing when they become calces, but only gain ſomething, is, that mercury becomes a calx, called *precipitate per ſe*, by imbibing pure air, and that it becomes running mercury again by parting with it.

This is acknowledged: but it is almoſt the only caſe of any calx being revived without the help of ſome known phlogiſtic ſubſtance; and in this particular caſe it is not abſurd to ſuppoſe, that the mercury, in becoming precipitate per ſe, may retain all its phlogiſton, as well as imbibe pure air, and therefore be revived by ſimply parting with that air. In many other caſes the ſame metal, in different ſtates, contains more or leſs phlogiſton, as caſt iron, malleable iron, and ſteel. Alſo there is a calx of mercury made by the acid of vitriol, which cannot be revived without the help of inflammable air, or ſome other ſubſtance ſuppoſed to contain phlogiſton: and that the inflammable air is really imbibed in theſe proceſſes, is evident, from its wholly diſappearing, and nothing being left in the veſſel in which the proceſs is made beſide the metal that is revived by it. If precipitate per ſe be revived in inflammable air, the air will be imbibed, ſo that running mercury may contain more or leſs phlogiſton.

The antiphlogiſtians alſo ſay, that the diminution of atmoſpherical air by the burning of phoſphorus is a proof of their theory; the pure air being imbibed by that ſubſtance, and nothing emitted from it. But there is the ſame proof of phoſphorus containing phlogiſton, that there is of dry fleſh containing it; ſince the produce of the ſolution of it in nitrous acid, and its effect upon the acid, are the ſame, viz. the production of phlogiſticated air, and the phlogiſtication of the acid.

Their proof that water is decompoſed, is, that in ſending ſteam over hot iron, inflammable air (which they ſuppoſe to be one conſtituent part of it) is procured; while the other part, viz. the oxygene, unites with the iron, and adds to its weight. But it is replied, that the inflammable air may be well ſuppoſed to be the phlogiſton of the iron, united to part of the water, as its baſe, while the remainder of the water is imbibed by the calx; and that it is mere water, and not pure air, or oxygene, that is retained in the iron, is evident, from nothing but pure water being recovered when this calx of iron is revived in inflammable air, in which caſe the inflammable air wholly diſappears, taking the place of the water, by which it had been expelled.

In anſwer to this it is ſaid, that the pure air expelled from the calx uniting with the inflammable air in the veſſel, recompoſes the water found after this proceſs. But in every other caſe in which any ſubſtance containing pure air is heated in inflammable air, though the inflammable air be in part imbibed, ſome *fixed air* is produced, and this fixed air is compoſed of the pure air in the ſubſtance and part of the inflammable air in the veſſel. Thus, if *minium*, which contains pure air, and *maſſicot*, which contains none, be heated in inflammable air, in both the caſes lead will be revived by the abſorption of inflammable air; but in the former caſe only, and not in the latter, will fixed air be produced. The calx of iron, therefore, having the ſame effect with maſſicot, when treated in the ſame manner, appears to contain no more pure air than maſſicot does.

Beſides this explanation of the facts on which the new theory is founded, which ſhews it to be unneceſſary, the old hypotheſis being ſufficient for the purpoſe, ſome facts are alledged, as inconſiſtent with the new doctrine.

If the calx of iron made by water, and charcoal made by the greateſt degree of heat, be mixed together, a great quantity of inflammable air will be produced; though, according to the new theory, neither of theſe ſubſtances contained any water, which they maintain to be the only origin of it. But this fact is eaſily explained upon the doctrine of phlogiſton; the water in this calx uniting with the phlogiſton of the charcoal, and then forming inflammable air; and it is the ſame kind of inflammable air that is made from charcoal and water.

Alſo the union of inflammable and pure air, when they are fired together by means of the electric ſpark, produces not pure water, as, according to the new theory, it ought to do, but *nitrous acid.*

To this it has been objected, that the acid thus produced came from the decompoſition of phlogiſticated air, a ſmall portion of which was at firſt contained in the mixture of the two kinds of air. But when every particle of phlogiſticated air is excluded, the ſtrongeſt acid is procured.

They find, indeed, that by the ſlow burning of inflammable air in pure air, they get pure water. But then it appears, that whenever this is the caſe, there is a production of phlogiſticated air, which contains the neceſſary element of nitrous acid; and this is always the caſe when there is a little ſurplus of the inflammable air that is fired along with the pure air, as the acid is always procured when there is a redundancy of pure air.

That much water ſhould be procured by the decompoſition of theſe kinds of air, is eaſily accounted for, by ſuppoſing that water, or ſteam, is the baſis of theſe, as well as of all other kinds of air.

Since air ſomething better than that of the atmoſphere is conſtantly produced from water by converting it into vapour, and alſo by removing the preſſure of the atmoſphere, and theſe proceſſes do not appear to have any limits; it ſeems probable, that *water* united to the principle of *heat*, conſtitutes atmoſpherical air; and if ſo, it muſt conſiſt of the elements of both dephlogiſticated and phlogiſticated air; which is a ſuppoſition very different from that of the French chemiſts.

LECTURE XXX.

Of Heat.

HEAT is an affection of bodies well known by the ſenſation that it excites. It is produced by friction or compreſſion, as by the ſtriking of flint againſt ſteel, and the hammering of iron, by the reflection or refraction of light, and by the combuſtion of inflammable ſubſtances.

It has been long diſputed, whether the cauſe of heat be properly a *ſubſtance*, or ſome particular affection of the particles that compoſe the ſubſtance that is heated. But be it a ſubſtance, or a principle of any other kind, it is capable of being transferred from one body to another, and the communication of it is attended with the following circumſtances. All ſubſtances are expanded by heat, but ſome in a greater degree than others; as metals more than earthy ſubſtances, and charcoal more than wood.

wood. Alſo ſome receive and tranſmit heat through their ſubſtance more readily than others; metals more ſo than earths, and of the metals, copper more readily than iron. Inſtruments contrived to aſcertain the expanſion of ſubſtances by heat, are called *pyrometers*, and are of various conſtructions.

As a ſtandard to meaſure the degrees of heat, mercury is in general preferable to any other ſubſtance, on account of its readily receiving, and communicating, heat through its whole maſs. *Thermometers*, therefore, or inſtruments to meaſure the degrees of heat, are generally conſtructed of it, though, as it is ſubject to become ſolid in a great degree of cold, ardent ſpirit, which will not freeze at all, is more proper in that particular caſe.

The graduation of thermometers is arbitrary. In that of Fahrenheit, which is chiefly uſed in England, the freezing point of water is 32°, and the boiling point 212°. In that of Reaumur, which is chiefly uſed abroad, the freezing point of water is 0, and the boiling point 80. To meaſure the degrees of heat above ignition, Mr. Wedgwood has happily contrived to uſe pieces of clay, which contract in the fire; and he has alſo been able to find the coincidence of the degrees in mercurial thermometers with thoſe of his own.

To meaſure the degrees of heat and cold during a perſon's abſence, Lord George Cavendiſh contrived an inſtrument, in which a ſmall baſon received the mercury, that was raiſed higher than the place for which it was regulated by heat or cold, without a power of returning. But Mr. Six has lately hit upon a better method, viz. introducing into the tube of his thermometer a ſmall piece of iron, which is raiſed by the aſcent of the mercury, and prevented from deſcending by a ſmall ſpring; but which may be brought back to its former place by a magnet acting through the glaſs.

Heat, like light, is propagated in right lines; and what is more remarkable, cold obſerves the ſame laws. For if the ſubſtance emitting heat without light, as iron below ignition, be placed in the focus of a burning a burning mirror, a thermometer in the focus of a ſimilar mirror, placed parallel to it, though at a conſiderable diſtance, will be heated by it, and if a piece of ice be placed there, the mercury will fall.

Heat aſſiſts the ſolvent power of almoſt all menſtrua; ſo that many ſubſtances will unite in a certain degree of heat, which will form no union at all without it, as dephlogiſticated and inflammable air.

If ſubſtances be of the ſame kind, they will receive heat from one another, in proportion to their maſſes. Thus, if a quantity of water heated to 40° be mixed with another equal quantity of water heated to 20°, the whole maſs will be heated to 30°. But if the ſubſtances be of different kinds, they will receive heat from each other in different proportions, according to their *capacity* (as it is called) of receiving heat. Thus, if a pint of mercury of the temperature of 136 be mixed with a pint of water of the temperature of 50, the temperature of the two after mixture will not be a medium between thoſe two numbers, viz. 93, but 76; conſequently the mercury was cooled 60°, while the water was heated only 26; ſo that 26 degrees of heat in water correſpond to 60 in mercury. But mercury is about 13 times ſpecifically heavier than water, ſo that an equal weight of mercury would contain only one thirtieth part of this heat; and dividing 26 by 13, the quotient is 2. If *weight*, therefore, be conſidered, the heat diſcovered by water ſhould be reckoned as 2 inſtead of 60; and conſequently when water receives 2 degrees of heat, an equal weight of mercury will receive 60°; and dividing both the numbers by 2, if the heat of water be 1, that of the mercury will be 30. Or ſince they receive equal degrees of heat, whether they diſcover it or not (and the leſs they diſcover, the more they retain in a latent ſtate) a pound of mercury contains no more than one thirtieth part of the heat actually exiſting in a pound of water of the ſame temperature. Water, therefore, is ſaid to have a greater capacity for receiving and retaining heat, without diſcovering it, than mercury, in the proportion of 30 to 1, if weight be conſidered, or of 60 to 26, that is of 30 to 13; if *bulk* be the ſtandard, though, according to ſome, it is as 3 to 2.

The capacity of receiving heat in the ſame ſubſtance is greateſt in a ſtate of vapour, and leaſt in that of a ſolid; ſo that when ice is converted into water, heat is abſorbed, and more ſtill when it is converted into vapour; and on the contrary, when vapour is converted into water, it gives out the heat which it had imbibed, and when it becomes ice it gives out ſtill more.

If equal quantities of ice and water be expoſed to heat at the temperature of 32°, the ice will only become water, without receiving any additional ſenſible heat; but an equal quantity of water in the ſame ſituation would be raiſed to 178°; ſo that 146 degrees of heat will be imbibed, and remain latent in the water, in conſequence of its paſſing from a ſtate of ice: and heat communicated by a given weight of vapour will raiſe an equal weight of a nonevaporable ſubſtance, of the ſame capacity with water, 943 degrees; ſo that much more heat is latent in ſteam, than in the water from which it was formed.

This doctrine of latent heat explains a great variety of phænomena in nature; as that of cooling bodies by evaporation, the vapour of water, or any other fluid ſubſtance, abſorbing and carrying off the heat they had before.

Water, perfectly at reſt, will fall conſiderably below the freezing point, and yet continue fluid: but on the ſlighteſt agitation, the congelation of the whole, or part of it, takes place inſtantly, and if the whole be not ſolid, it will inſtantly riſe to 32°, the freezing point. From whatever cauſe, ſome motion ſeems neceſſary to the commencement of congelation, at leaſt in a moderate temperature; but whenever any part of the water becomes ſolid, it gives out ſome of the heat it had before, and that heat which was before latent becoming ſenſible, and being diffuſed through the whole maſs, raiſes its temperature.

On the ſame principle, when water heated higher than the boiling point in a digeſter is ſuddenly permitted to eſcape in the form of ſteam, the remainder is inſtantly reduced to the common boiling point, the heat above that point being carried off in a latent ſtate by the ſteam.

Had it not been for this wiſe proviſion in nature, the whole of any quantity of water would, in all caſes of freezing, have become ſolid at once; and alſo the whole of any quantity that was heated to the point of boiling, would have been converted into ſteam at once; circumſtances which would have been extremely inconvenient, and often fatal.

This doctrine alſo explains the effect of freezing mixtures, as that of ſalt and ſnow. Theſe ſolid ſubſtances, on being mixed, become fluid, and that fluid abſorbing much heat, deprives all the neighbouring bodies of part of what they had. But if the temperature at which the mixture is made be as low as that to which this mixture would have brought it, it has no effect, and in a lower temperature this new fluid would become ſolid; for that mixture has only a certain determinate capacity for heat, and if the neighbouring bodies have leſs heat, they will take from it.

It has been obſerved, that the comparative heat of bodies containing phlogiſton is increaſed by calcination or combuſtion; ſo that the calx of iron has a greater capacity for heat, and therefore contains more latent heat, than the metal.

In general it is not found, that the ſame ſubſtances have their capacity for receiving heat increaſed by an increaſe of temperature; but this is ſaid to be the caſe with a mixture of ardent ſpirit and water, and alſo that of ſpirit of vitriol and water.

Since all ſubſtances contain a greater or leſs quantity of heat, and in conſequence of being deprived of it become colder and colder, it is a queſtion of ſome curioſity to determine the extent to which this can go, or at what degree in the ſcale of a thermometer any ſubſtance would be abſolutely cold, or deprived of all heat; and an attempt has been made to ſolve this problem in the following manner. Comparing the capacity of water with that of ice, by means of a third ſubſtance, viz.

mercury, it has been found, that if that of ice be 9°, that of water is 10°; ſo that water in becoming ice gives out one tenth part of its whole quantity of heat. But it has been ſhown, that ice in becoming water abſorbs 146 degrees of heat. This, therefore, being one tenth part of the whole heat of water, it muſt have contained 1460 degrees; ſo that taking 32 degrees, which is the freezing point, from that number, the point of abſolute cold will be 1426 below 0 of Fahrenheit's ſcale.

By a computation, made by means of the heat of inflammable and dephlogiſticated air, at the temperature of 50, Dr. Crawford finds, that it contains nearly 1550 degrees of heat; ſo that the point of abſolute cold will be 1500 below 0. But more experiments are wanted to ſolve this curious problem to entire ſatisfaction.

LECTURE XXXI.

Of Animal Heat.

SINCE all animals, and eſpecially thoſe that have red blood, are much hotter than the medium in which they live, the ſource of this heat has become the ſubject of much inveſtigation; and as the moſt probable theory is that of Dr. Crawford, I ſhall give a ſhort detail of the reaſons on which it is founded.

Having, with the moſt ſcrupulous attention, aſcertained the *latent*, or, as he calls it, the *abſolute* heat of blood, and alſo that of the aliments of which it is compoſed, he finds that it contains more than could have been derived from *them*. Alſo finding that the abſolute heat of arterial blood exceeds that of venous blood, in the proportion of 11½ to 10, he concludes that it derives its heat from the air reſpired in the lungs, and that it parts with this *latent* heat, ſo that it becomes ſenſible, in the courſe of its circulation, in which it becomes loaded with phlogiſton, which it communicates to the air in the lungs.

That this heat is furniſhed by the *air*, he proves, by finding, that that which we inſpire contains more heat than that which we expire, or than the aqueous humor which we expire along with it, in a very conſiderable proportion; ſo that if the heat contained in the pure air did not become latent in the blood, it would raiſe its temperature higher than that of red-hot iron. And again, if the venous blood, in being converted into arterial blood, did not receive a ſupply of latent heat from the air, its temperature would fall from 96 to 104 below 0 in Fahrenheit's thermometer.

That the heat procured by combuſtion has the ſame ſource, viz. the dephlogiſticated air that is decompoſed in the proceſs, is generally allowed; and Dr. Crawford finds, that when equal portions of air are altered by the reſpiration of a Guinea pig, or by the burning of charcoal, the quantity of heat communicated by the two proceſſes is nearly equal.

The following facts are alſo alleged in favour of his theory. Whereas animals which have much red blood, and reſpire much, have the power of keeping themſelves in a temperature conſiderably higher than that of the ſurrounding atmoſphere, other animals, as *frogs* and *ſerpents*, are nearly of the ſame temperature with it; and thoſe animals which have the largeſt reſpiratory organs, as birds, are the warmeſt; alſo the degree of heat is in ſome meaſure proportionable to the quantity of air that is reſpired in a given time, as in violent exerciſe.

It has been obſerved, that animals in a medium hotter than the blood have a power of preſerving themſelves in the ſame temperature. In this caſe the heat is probably carried off by perſpiration, while the blood ceaſes to receive, or give out, any heat; and Dr. Crawford finds, that when an animal is placed in a warm medium the colour of the venous blood approaches nearer to that of the arterial than when it is placed in a colder medium; and alſo, that it phlogiſticates the air leſs than in the former caſe; ſo that in theſe circumſtances reſpiration has not the ſame effect that it has in a colder temperature, in giving the body an additional quantity of heat; which is an excellent proviſion in nature, as the heat is not wanted, but, on the contrary, would prove inconvenient.

LECTURE XXXII.

Of Light.

ANOTHER moſt important agent in nature, and one that has a near connexion with heat, is *light*, being emitted by all bodies in a ſtate of ignition, and eſpecially by the ſun, the great ſource of light and of heat to this habitable world.

Whether light conſiſts of particles of

matter (which is moſt probable) or be the undulation of a peculiar fluid, filling all ſpace, it is emitted from all luminous bodies in right lines.

Falling upon other bodies, part of the light is *reflected* at an angle equal to that of its incidence, though not by impinging on the reflecting ſurface, but by a power acting at a ſmall diſtance from it. But another part of the light enters the body, and is *refracted* or bent *towards*, or *from*, the perpendicular to the ſurface of the new medium, if the incidence be oblique to it. In general, rays of light falling obliquely on any medium are bent as if they were attracted by it, when it has a greater denſity, or contains more of the inflammable principle, than the medium through which it was tranſmitted to it. More of the rays are reflected when they fall upon a body with a ſmall degree of obliquity to its ſurface, and more of them are tranſmitted, or enter the body, when their incidence is nearer to a perpendicular.

The velocity with which light is emitted or reflected is the ſame, and ſo great that it

paſſes

paſſes from the ſun to the earth in about eight minutes and twelve ſeconds.

Rays of light emitted or reflected from a body entering the pupil of the eye, are ſo refracted by the humours of it, as to be united at the ſurface of the retina, and ſo make images of the objects, by means of which they are viſible to us; and the magnifying power of teleſcopes or microſcopes depends upon contriving, by means of reflections or refractions, that pencils of rays iſſuing from every point of any object ſhall firſt diverge, and then converge, as they would have done from a much larger object, or from one placed much nearer to the eye.

When a beam of light is bent out of its courſe by refraction, all the rays of which it conſiſts are not equally refracted, but ſome of them more and others leſs; and the colour which they are diſpoſed to exhibit is connected invariably with the degree of their refrangibility; the red-coloured rays being the leaſt, and the violet the moſt refrangible, and the reſt being more or leſs ſo in proportion to their nearneſs to theſe, which are the extremes, in the following order, violet, indigo, blue, green, yellow, orange, red.

Theſe colours, when ſeparated as much as poſſible, are ſtill contiguous; and all the ſhades of each colour have likewiſe their ſeparate and invariable degrees of refrangibility. When ſeparated as diſtinctly as poſſible, they divide the whole ſpace between them exactly as a muſical chord is divided in order to ſound the ſeveral notes and half notes of an octave.

Theſe differently-coloured rays of light are alſo ſeparated in paſſing through the tranſparent medium of air and water, in conſequence of which the ſky appears blue and the ſea green, theſe rays being returned, while the red ones proceed to a greater diſtance. By this means alſo objects at the bottom of the ſea appear to divers red, and ſo do all objects enlightened by an evening ſun.

The mixture of all the differently-coloured rays, in the proportions in which they cover the coloured image above mentioned, makes a *white*, and the abſence of all light is *blackneſs*.

By means of the different refrangibility of light, the colours of the rainbow may be explained.

The diſtance to which the differently-coloured rays are ſeparated from each other is not in proportion to the mean refractive power of the medium, but depends upon the peculiar conſtitution of the ſubſtance by which they are refracted. The *diſperſing power* of glaſs, into the compoſition of which *lead* enters, is great in proportion to the mean refraction; and it is proportionally little in that glaſs in which there is much alkaline ſalt. The conſtruction of *achromatic teleſcopes* depends upon this principle.

Not only have different rays of light theſe different properties with reſpect to bodies, ſo as to be more or leſs refracted, or diſperſed, by them, but different ſides of the ſame rays ſeem to have different properties, for they are differently affected on entering a piece of *iſland cryſtal.* With the ſame degree of incidence, part of the pencil of rays, conſiſting of all the colours, proceeds in one direction, and the reſt in a different a different one; ſo that objects ſeen through a piece of this ſubſtance appear double.

At the ſurface of all bodies rays of light are promiſcuouſly reflected, or tranſmitted.

But if the next ſurface be very near to it, the rays of one colour chiefly are reflected, and the reſt tranſmitted, and theſe places occur alternately for rays of each of the colours in paſſing from the thinneſt to the thickeſt parts of the medium; ſo that ſeveral ſeries, or orders, of colours will be viſible on the ſurface of the ſame thin tranſparent body. On this principle coloured rings appear between a plane and a convex lens, in a little oil on the ſurface of water, and in bubbles made with ſoap and water.

When rays of light paſs near to any body, ſo as to come within the ſphere of its attraction and repulſion, an *inflection* takes place; all the kinds of rays being bent *towards*, or *from*, the body, and theſe powers affecting ſome rays more than others, they are by this means alſo ſeparated from each other, ſo that coloured ſtreaks appear both within the ſhadow, and on the outſide of it, the red rays being inflected at the greateſt diſtance from the body.

Part of the light which enters bodies is retained within them, and proceeds no farther; but ſo looſely in ſome kinds of bodies, that a ſmall degree of heat is ſufficient to expel it again, ſo as to make the body viſible in the dark: but the more heat is applied, the ſooner is all the light expelled. This is a ſtrong argument for the materiality of light. *Bolognian phoſphorus* is a ſubſtance which has this property; but a compoſition made by Mr. Canton, of calcined oyſter-ſhells and ſulphur, in a much greater degree. However, white paper, and moſt ſubſtances, except the metals, are poſſeſſed of this property in a ſmall degree.

Some bodies, eſpecially phoſphorus, and animal ſubſtances tending to putrefaction, emit light without being ſenſibly hot.

The *colours* of vegetables, and likewiſe their *taſte* and *ſmell*, depend upon light. It is alſo by means of light falling on the leaves and other green parts of plants, that they emit dephlogiſticated air, which preſerves the atmoſphere fit for reſpiration.

It is light that imparts colour to the ſkins of men, by means of the fluid immediately under them. This is the cauſe of *tanning*, of the *copper colour* of the North Americans, and the *black* of the Negroes. Light alſo gives colour to ſeveral other ſubſtances, eſpecially the ſolutions of mercury in acids.

LECTURE XXXIII.

Of Magnetiſm.

MAGNETISM is a property peculiar to iron, or ſome ores of it. The earth itſelf, owing probably to the iron ores contained in it, has the ſame property. But though all iron is acted upon by magnetiſm, *ſteel* only on the outſide of it, the red rays being inflected at the greateſt diſtance from the body.

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Every magnet has two poles, denominated *north* and *ſouth*, each of which attracts the other, and repels that of the ſame kind with itſelf. If a magnet be cut into two parts, between the two poles, it will make two magnets, the parts that were contiguous becoming oppoſite poles.

Though the poles of a magnet are denominated *north* and *ſouth*, they do not conſtantly, and in all parts of the earth, point due north or ſouth, but in moſt places to the eaſt or weſt of them, and with a conſiderable variation in a courſe of time. Alſo a magnet exactly balanced at its center will have a declination from an horizontal poſition of about 70 degrees. The former is called the *variation*, and the latter the *dipping* of the magnetic needle.

A ſtraight bar of iron which has been long fixed in a vertical poſition, will become a magnet, the lower end becoming a north pole, and the upper end a ſouth one; for if it be ſuſpended horizontally, the lower end will point towards the north, and the upper end towards the ſouth. Alſo any bar of iron, not magnetical, held in a vertical poſition, will become a temporary magnet, the lower end becoming a north pole, and the upper end a ſouth one; and a few ſtrokes of a hammer will fix the poles for a ſhort time, though the poſition of the ends be changed. Magnetiſm may likewiſe be given to a bar of iron by placing it firmly in the poſition of the dipping-needle, and rubbing it hard one way with a poliſhed ſteel inſtrument. Iron will alſo become magnetical by ignition and quenching it in water in the poſition of the dipping-needle.

Magnetiſm acts, without any diminution of its force, through any medium; and iron not magnetical will have that power while it is in connexion with a magnet, or rather the power of the magnet is extended through the iron.

Steel filings gently thrown upon a magnet, adhere to it in a curious manner; and the filings, acquiring magnetiſm by the contact, adhere together, and form a number of ſmall magnets, which arrange themſelves according to the attraction of the poles of the original magnet. This experiment is made to the moſt advantage upon a piece of paſteboard, or paper, placed over the magnet.

Magnetiſm is communicated by the friction, or the near poſition, of a magnet to a piece of ſteel of a ſize leſs than it. For this reaſon a combination of magnetical bars will have a greater effect than a ſingle one; and in the following manner, beginning without any magnetiſm at all, the greateſt quantity may be procured. Six bars of ſteel may be rendered ſlightly magnetical by fixing each of them ſucceſſively to an upright poker, and ſtroking it ſeveral times from the bottom to the top with the lower end of an old pair of tongs. If then four of theſe bars be joined, the magnetiſm of the remaining two will be much increaſed by a proper method of rubbing with them; and by changing their places, joining the ſtrongeſt, and acting upon the weakeſt, they may all be made as magnetical as they are capable of being.

The ſtrength of a natural magnet may

be increaſed by covering its polar extremities with ſteel. This is called the *arming* of the loadſtone.

To account for the variation of the needle, Dr. Halley ſuppoſed the earth to conſiſt of two parts, an external *ſhell* and an internal *nucleus*, detached, and having a revolution diſtinct from it; and that the action of the poles of the ſhell and of the nucleus would explain all the varieties in the poſition of the needle. But others think that the cauſe of the magnetiſm of the earth is not *within*, but *without* itſelf. One reaſon for this opinion is, that a magnet is liable to be affected by a ſtrong aurora borealis; and another is, that the variation of the needle proceeds in ſuch a manner as ſuppoſes that the motion of the nucleus muſt be quicker than that of the ſhell of the earth; whereas, ſince it is moſt natural to ſuppoſe that motion was communicated to the nucleus by the ſhell, it would be ſlower.

Some idea of the quantity and the progreſs of the variation of the needle may be formed from the following facts.—At the

Cape of Good Hope, when it was diſcovered by the Portugueſe, in 1486, there was no variation, the needle there pointing due north; in 1622 it was about 2 degrees weſtward, in 1675 it was 8° W. in 1700 about 11° W. in 1756 about 18° W. and in 1774 about 21½ W. In London, in 1580, the variation was 11 degrees 15 ſeconds E.; in 1622 it was 6° E. in 1634 it was 4 deg. 5 min. E. in 1657 it was nothing at all; in 1672 it was 2 deg. 30 min. W. in 1692 it was 6 deg. W. in 1753 it was about 16 W. and at preſent it is about 21 W.

The longitude may in ſome places be found by the variation of the needle; and Mr. Churchman, of America, having given much attention to the ſubject, comparing the obſervations of others, and many of his own, thinks that he has found a method of determining the longitude to a great degree of certainty, in moſt caſes, by this means.

He ſays there are two magnetic poles of the earth, one to the north and the other to the ſouth, at different diſtances from the poles of the earth, and revolving in different times; and from the combined influence of theſe two poles he deduces rules for the poſition of the needle in all places of the earth, and at all times, paſt, preſent, or to come.

The north magnetic pole, he ſays, makes a complete revolution in 426 years, 77 days, 9 hours, and the ſouth pole in about 5459 years. In the beginning of the year 1777 the north magnetic pole was in 76 deg. 4 min. north latitude; and in longitude from Greenwich 140 deg. eaſt; and the ſouth was in 72 deg. ſouth latitude, and 140 deg. eaſt from Greenwich.

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LECTURE XXXIV.

Of Electricity.

ELECTRICITY is a property belonging to, or capable of being communicated to, all ſubſtances whatever; and whereas by ſome of them it is tranſmitted with great eaſe, and by others with much difficulty, they have been divided into two claſſes, and denominated *conductors* or *non-conductors* of electricity. Alſo the latter receiving this power by friction, and other means, are termed *electrics*, and the former *non-electrics*.

Metals of all kinds, and water, are conductors, though in very different degrees; ſo alſo is charcoal. All other ſubſtances, and alſo a perfect vacuum, are non-conductors of electricity. But many of theſe ſubſtances, when they are made very hot, as glaſs, reſin, baked wood, and perhaps all the reſt on which the experiment can be made in this ſtate, are conductors.

It is the property of all kinds of electrics, when they are rubbed by bodies different from themſelves, to attract light ſubſtances of all kinds, to exhibit an appearance of *light*, attended with a particular *ſound*, on the approach of any conductor; and if the noſtrils are preſented, they are affected with a *ſmell* like that of phoſphorus. This attraction is moſt eaſily explained by ſuppoſing that electricity is produced by a fluid exceedingly elaſtic, or repulſive of itſelf, and attracted by all other ſubſtances.

An electric exhibiting the appearances above mentioned, is ſaid to be *excited*, and ſome of them, particularly the *tourmaline*, are excited by heating and cooling, as well as by friction. It appears, however, that excitation conſiſts in the mere transferring of electricity from one ſubſtance to another, and that the great ſource of electricity is in the earth. On this account it is neceſſary to the conſiderable excitation of any electric, that the ſubſtance againſt which it is rubbed (hence termed *the rubber*) have a communication with the earth, by means of conductors; for if the rubber be *inſulated*, that is cut off from all communication with the earth by means of electrics, the friction has but little effect.

When inſulated bodies have been attracted by, and brought into contact with, an excited electric, they begin to be repelled by it, and alſo to repel one another; nor will they be attracted again till they have been brought into contact with ſome conductor communicating with the earth; but after this they will be attracted as at firſt.

If conductors be *inſulated*, electric powers may be communicated to them by the approach of excited electrics, or the contact of other electrified bodies. They will then attract light bodies, and give ſparks, &c. like the excited electrics themſelves.

When electricity is ſtrongly communicated to inſulated animal bodies, the pulſe is quickened, and perſpiration increaſed; and if they receive, or part with, their electricity on a ſudden, a painful ſenſation is felt at the place of communication. But what is more extraordinary, is, that the influence of the brain and nerves upon the muſcles ſeems to be of an electric nature.

This is one of the laſt and moſt important of all philoſophical diſcoveries. I ſhall, therefore, give the reſult of all the obſervations that have hitherto been made on the ſubject, in a *ſeries of propoſitions*, drawn up by an intelligent friend, who has given much more attention to it than I have done.

1. The nerve of the limb of an animal being laid bare, and ſurrounded with a piece of ſheet lead, or of tinfoil, if a communication be formed between the nerve thus armed and any of the neighbouring muſcles, by means of a piece of zinc, ſtrong contractions will be produced in the limb.

2. If a portion of the nerve which has been laid bare be armed as above, contractions will be produced as powerfully, by forming the communication between the armed and bare part of the nerve, as between the armed part and muſcle.

3. A ſimilar effect is produced by arming a nerve and ſimply touching the armed

part of the nerve with the metallic conductor.

4. Contractions will take place if a muſcle be armed, and a communication be formed by means of the conductor between it and a neighbouring nerve. The ſame effect will be produced if the communication be formed between the armed muſcle and another muſcle, which is contiguous to it.

5. Contractions may be produced in the limb of an animal by bringing the pieces of metal into contact with each other at ſome diſtance from the limb, provided the latter make part of a line of communication between the two metallic conductors.

The experiment which proves this is made in the following manner. The amputated limb of an animal being placed upon a table, let the operator hold with one hand the principal nerve, previouſly laid bare, and in the other let him hold a piece of zinc; let a ſmall plate of lead or ſilver be then laid upon the table, at ſome diſtance from the limb, and a communication be formed, by means of water, between the limb and the part of the table where the metal is lying. If the operator touch the piece of ſilver with the zinc, contractions will be produced in the limb the moment that the metals come into contact with each other. The ſame effect will be produced if the two pieces of metal be previviouſly placed in contact, and the operator touch one of them with his finger. This fact was diſcovered by Mr. William Cruikſhank.

6. Contractions can be produced in the amputated leg of a frog, by putting it into water, and bringing the two metals into contact with each other at a ſmall diſtance from the limb.

7. The influence which has paſſed through, and excited contractions in, one limb, may be made to paſs through, and excite contractions in, another limb. In performing this experiment it is neceſſary to attend to the following circumſtances: let two amputated limbs of a frog be taken; let one of them be laid upon a table, and its foot be folded in a piece of ſilver; let a perſon lift up the nerve of this limb with a ſil-

ver probe, and another perſon hold in his hand a piece of zinc, with which he is to touch the ſilver including the foot; let the perſon holding the zinc in one hand catch with the other the nerve of the ſecond limb, and he who touches the nerve of the firſt limb is to hold in his other hand the foot of the ſecond; let the zinc now be applied to the ſilver including the foot of the firſt limb, and contractions will immediately be excited in both limbs.

8. The heart is the only involuntary muſcle in which contractions can be excited by theſe experiments.

9. Contractions are produced more ſtrongly, the farther the coating is placed from the origin of the nerve.

10. Animals which were almoſt dead have been found to be conſiderably revived by exciting this influence.

11. When theſe experiments are repeated upon an animal that has been killed by opium, or by the electric ſhock, very ſlight contractions are produced; and no contractions whatever will take place in an animal that has been killed by corroſive

ſublimate, or that has been ſtarved to death.

12. Zinc appears to be the beſt exciter when applied to gold, ſilver, molybdena, ſteel, or copper. The latter metals, however, excite but feeble contractions when applied to each other. Next to zinc, in contact with theſe metals, tin and lead, and ſilver and lead, appear to be the moſt powerful exciters.

At leaſt two kinds of fiſhes, the *torpedo* and the *electrical eel*, have a voluntary power of giving ſo ſtrong a ſhock to the water in which they ſwim, as to affect fiſhes and other animals which come near them; and by a conducting communication between different parts of theſe fiſhes, an electric ſhock may be given exactly like that of the Leyden phial, which will be deſcribed hereafter; and if the communication be interrupted, a flaſh of electric light will be perceived.

The growth of vegetables is alſo quickened by electricity.

LECTURE XXXV.

The ſame Subject continued.

No electric can be excited without producing electric appearances in the body with which it is excited, provided that body be inſulated; for this inſulated rubber will attract light bodies, give ſparks, and make a ſnapping noiſe, upon the approach of a conductor, as well as the excited electric.

If an inſulated conductor be pointed, or if a pointed conductor, communicating with the earth, be held pretty near it, little or no electric appearance will be exhibited, only a light will appear at each of the points during the act of excitation, and a current of air will be ſenſible from off them both.

The effect of pointed bodies is beſt explained on the ſuppoſition of the electric matter in one body repelling that in another; and conſequently the electricity belonging to a body with a large ſurface making a greater reſiſtance to the entrance of foreign electricity than that belonging to a ſmaller.

Theſe two electricities, viz. that of the excited electric, and that of the rubber, though ſimilar to, are the reverſe of, one another. A body attracted by the one will be repelled by the other, and they will attract, and in all reſpects act upon, one another more ſenſibly than upon other bodies; ſo that two pieces of glaſs or ſilk poſſeſſed of contrary electricities will cohere firmly together, and require a conſiderable force to ſeparate them.

Theſe two electricities having been firſt diſcovered by producing one of them from glaſs, and the other from amber, ſealing-wax, ſulphur, roſin, &c. firſt obtained the names of *vitreous* and *reſinous* electricity; and it being afterwards imagined that one of them was a redundancy, and the other a deficiency, of a ſuppoſed electric fluid, the former has obtained the name of *po-*

ſitive, and the latter that of *negative*, electricity; and theſe terms are now principally in uſe.

Poſitive and negative electricity may be diſtinguiſhed from each other by the manner in which they appear at the points of bodies. From a pointed body electrified poſitively, there iſſues a ſtream of light, divided into denſer ſtreams, at the extremities; whereas, when the point is electrified negatively, the light is more minutely divided, and diffuſed equally. The former of theſe is called a *bruſh*, and the latter a *ſtar*.

If a conductor not inſulated be brought within the atmoſphere (that is the ſphere of action) of any electrified body, it acquires the electricity oppoſite to that of the electrified body, and the nearer it is brought, the ſtronger oppoſite electricity does it acquire, till the one receive a ſpark from the other, and then the electricity of both will be diſcharged.

The electric ſubſtance which ſeparates the two conductors poſſeſſing theſe two oppoſite kinds of electricity, is ſaid to be *charged.*

charged. Plates of glaſs are the moſt convenient for this purpoſe, and the thinner the plate the greater is the charge it is capable of holding. The conductors contiguous to each ſide of the glaſs are called their *coating.*

Agreeably to the above-mentioned general principle, it is neceſſary that one ſide of the charged glaſs have a communication with the rubber, while the other receives the electricity from the conductor, or with the conductor, while the other receives from the rubber.

It follows alſo, that the two ſides of the plate thus charged are always poſſeſſed of the two oppoſite electricities; that ſide which communicates with the excited electric having the electricity of the electric, and that which communicates with the rubber, that of the rubber.

There is, conſequently, a very eager attraction between theſe two electricities with which the different ſides of the plate are charged, and when a proper communication is made by means of conductors, a flaſh of electric light, attended with a report (which is greater or leſs in proportion to the quantity of electricity communicated to them, and the goodneſs of the conductors) is perceived between them, and the electricity of both ſides is thereby diſcharged.

The ſubſtance of the glaſs itſelf in, or upon, which theſe electricities exiſt, is impervious to electricity, and does not permit them to unite; but if they be very ſtrong, and the plate of glaſs very thin, they will force a paſſage through the glaſs. This, however, always breaks the glaſs, and renders it incapable of another charge.

The flaſh of light, together with the exploſion between the two oppoſite ſides of a charged electric, is generally called the *electric ſhock*, on account of the diſagreeable ſenſation it gives any animal whoſe body is made uſe of to form the communication been them.

The electric ſhock is always found to perform the circuit from one ſide of the charged glaſs to the other by the ſhorteſt paſſage through the beſt conductors. Common communicated electricity alſo obſerves the ſame rule in its tranſmiſſion from one body to another.

It has not been found, that the electric ſhock takes up any ſenſible ſpace of time in being tranſmitted to the greateſt diſtances.

The electric ſhock, as alſo the common electric ſpark, diſplaces the air through which it paſſes; and if its paſſage from conductor to conductor be interrupted by non-conductors of a moderate thickneſs, it will rend and tear them in its paſſage, in ſuch a manner as to exhibit the appearance of a ſudden expanſion of the air about the center of the ſhock.

If the electric circuit be interrupted, the electric matter, during the diſcharge, will paſs to any other body that lies near its path, and inſtantly return. This may be called the *lateral exploſion.* The effect of this lateral exploſion through a braſs chain, when the quantity of electricity is very great, will be the diſcolouring and partial burning of the paper on which it lies.

If a great quantity of electricity be accumulated, as in a *battery*, the exploſion will paſs over the ſurfaces of imperfect conductors without entering them, and the effect will be a ſtrong *concuſſion* of the ſubſtance. Alſo the electric matter thus accumulated and condenſed will, by its repulſion, form *concentric circles*, which will appear by melting the ſurface of a flat piece of metal on which the exploſion is received.

If an electric ſhock, or ſtrong ſpark, be made to paſs through, or over, the belly of a muſcle, it forces it to contract, as in a convulſion.

If a ſtrong ſhock be ſent through a ſmall animal body, it will often deprive it inſtantly of life.

When the electric ſhock is very ſtrong, it will give polarity to magnetic needles, and ſometimes it reverſes their poles.

Great ſhocks, by which animals are killed, are ſaid to haſten putrefaction.

Electricity and lightning are in all reſpects the ſame thing; ſince every effect of lightning may be imitated by electricity, and every experiment in electricity may be made with lightning, brought down from the clouds by means of inſulated pointed rods of metal.

LECTURE XXXVI.

The ſame Subject continued.

THREE curious and important inſtruments, which are among the lateſt improvements in electricity, deſerve a particular explanation, and in all of them the effect depends upon the general principles mentioned above, viz. that bodies placed within the influence, or, as it is uſually termed, within the atmoſphere, of an electrified body, are affected by a contrary electricity, and that theſe two electricities mutually attract each other. Theſe inſtruments are the *electrophorus*, the *condenſer* of electricity, and the *doubler* of it.

The electrophorus conſiſts of an inſulated conducting plate applied to an inſulated electric. If the latter have any electricity communicated to it, for example the negative, the poſitive electricity of the former will be attracted by it, and conſequently the plate will be capable of receiving electricity from any body communicating with the earth; being, in this ſituation, capable of containing more electricity than its natural quantity. Conſequently, when it is removed from the lower plate, and the whole of its electricity equally diffuſed through it, it will appear to have a redundance, and therefore will give a ſpark to any body communicating with the earth. Being then replaced upon the electric, and touched by any body communicating with the earth, it will be again affected as before, and give a ſpark on being raiſed; and this proceſs may be continued at pleaſure, the electrophorus ſupplying the place of any other electrical machine.

If the conducting plate of the electrophorus be applied to a piece of dry wood, marble, or any other ſubſtance through which electricity can paſs but very ſlowly, or if the inſulated conducting plate be covered with a piece of thin ſilk, which will make ſome reſiſtance to the paſſage of electricity, and it be then applied to another plate communicating with the earth; and if, in either of theſe caſes, a body with a large ſurface poſſeſſed of a weak electricity be applied to the conducting plate, the weak electricity not being able to overcome the obſtruction preſented to it, ſo as to be communicated to the other plate, will affect it with the contrary electricity, and this reacting on the firſt plate, will condenſe its electricity on that part of the plate to which it is contiguous; in conſequence of which its capacity of receiving electricity will be increaſed; ſo that on the ſeparation of the two plates, that electricity which was before condenſed, being equally diffuſed through the whole plate, will have a greater intenſity than it had before, attracting light bodies, or even giving a ſpark, when the body from which it received its electricity was incapable of it. For though it contained a great quantity of electricity, it was diffuſed through ſo large a ſpace that its intenſity was very ſmall. This inſtrument is therefore called a *condenſer of electricity.*

If an inſulated plate of metal poſſeſſing the ſmalleſt degree of electricity be preſented very near to another plate communicating with the earth, it will affect this plate with the oppoſite electricity; and this being, in the ſame manner, applied to a third plate, will put it into the ſame ſtate with the firſt. If then theſe two plates be joined, and the firſt plate be preſented to either of them, its own electricity being attracted by that of the plate preſented, that of the other will be drawn into it, ſo that its quantity will be doubled. The ſame proceſs being repeated, will again double the electricity of this plate, till, from being quite inſenſible to the moſt exquiſite electrometer, it will become very conſpicuous, or even give ſparks. This inſtrument is therefore called a *doubler of electricity*, of excellent uſe in aſcertaining the quality of atmoſpherical electricity when ever ſo ſmall. If this inſtrument be ſo conſtructed that theſe three plates can be ſucceſſively preſented to one another by the revolution of one of them on an axis, it is called the *revolving doubler*; and in this form it is moſt convenient for uſe.

THE END.

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